Chapter 2
WATERSHED AND TRIBUTARY WATER QUALITY

The Lake Okeechobee watershed is dominated by agriculture, which contributes nutrients and other pollutants that have impacted the ecological condition of Lake Okeechobee. Phosphorus is of particular concern in this system because it has been identified as the key element that contributes to the eutrophication of the lake (Davis and Marshall, 1975; Federico et al*.,* 1981; Joyner 1972; Kissimmee-Okeechobee Basin Report, 1972). To restore the ecological condition of Lake Okeechobee, a 40 percent phosphorus load reduction goal was developed based on data collected from 1973 to 1979 (Federico et al., 1981). The SWIM Act (Section 373.451-.459, F.S.) was passed in 1987 requiring that a program be established to reduce phosphorus loads to Lake Okeechobee by this amount.

The *Interim Lake Okeechobee SWIM Plan* (SFWMD, 1989a) set forth a recommended approach for meeting the 40 percent phosphorus reduction goal. According to the plan, all tributary inflows to the lake were required to meet the 0.18 milligrams per liter (mg/l) (180 ppb) performance limitation for total phosphorus or maintain their 1989 discharge concentration, whichever was less. Basins that exceeded the 0.18 mg/l limitation were required to reduce their phosphorus concentrations and achieve compliance by July 1992.

Strategies have been developed to reach these reduction loading goals. These include continuing to implement the Works of the District (WOD) Program, implementing the CERP, developing BMPs for agriculture, continuing to model load reduction scenarios, and implementation of the Lake Okeechobee Protection Program and Permits (Section 373.4595(3)-(4), F.S.).

Strategies have also been developed to achieve State Class I Water Quality Standards within Lake Okeechobee and Class III Water Quality Standards within the lake’s tributaries. These standards are set forth in Chapter 62-302.530, F.A.C.

A. GOALS, OBJECTIVES, AND STRATEGIES

Goal 1: Reduce pollutant loads from the watershed to protect aquatic life and water quality in Lake Okeechobee

Objective 1: Bring the overtarget basins down to their phosphorus loading targets

Strategy 1: Continue to implement the WOD Program and develop nutrient management plans for out-of-compliance parcels

Strategy 2: Implement the CERP initiatives to reduce the loads to the lake through reservoir-assisted stormwater treatment areas

Strategy 3: Develop BMPs for agriculture and continue modeling load reduction scenarios

Objective 2: Develop and implement the components of the Lake Okeechobee Protection Program and Permits to meet the TMDL target by 2015

Strategy 1: Identify any health or environmental problems associated with spreading wastewater residuals and chicken manure on land

Strategy 2: Institute best available technologies (BATs) on selected dairies to significantly reduce the export of phosphorus into Lake Okeechobee tributaries

Strategy 3: Implement a nonregulatory, landowner-based initiative for on-site retention of phosphorus and water through the Lake Okeechobee Water Retention/Phosphorus Removal Critical Restoration Project

Strategy 4: Restore or create isolated wetlands in association with the implementation of BMPs to reduce the phosphorus loading from beef cattle operations and other land uses in the watershed

Strategy 5: Implement the Phosphorus Source Control Grant Program to fund load reduction projects proposed by applicants

Strategy 6: Evaluate two methods of sediment removal technologies selected as part of the sediment removal project under way in Lettuce Creek

Strategy 7: Conduct an economic analysis of all feasible on-farm and regional phosphorus control alternatives to reduce phosphorus loads to the recommended levels

Objective 3: Achieve State Class I Water Quality Standards (Chapter 62-302, F.A.C.) within Lake Okeechobee, and Class III Water Quality Standards within the lake's tributaries

Strategy 1: Support the development and implementation of a comprehensive plan to address the occurrence of Class I/Class III water quality criteria being exceeded within Lake Okeechobee and its tributaries to fulfill the requirements of the Lake Okeechobee Operating Permit

Strategy 2: Establish additional monitoring of biological conditions and trace metals during inflow conditions to document whether the inflows from tributaries to Lake Okeechobee meet the standards of their designated usage class

Strategy 3: Establish monitoring to determine the significance of and the potential causes of low dissolved oxygen in inflows from tributaries to the lake before management strategies are evaluated

Strategy 4: Sample the tributaries for total dissolved solids on a regular basis, since Class I criterion for total dissolved solids was exceeded over 25 percent of the time in inflows from the tributaries to Lake Okeechobee

Strategy 5: Modify the District's monthly monitoring program to include iron analysis to facilitate a more conclusive assessment of the potential need for management measures to control trace metals within the tributaries

Strategy 6: Reduce the list of organic parameters from the supplemental monitoring program to focus on compounds that are known to have potential sources in the watershed, such as pesticides, herbicides, and petroleum hydrocarbons

Strategy 7: Recommend quarterly sampling for organics, with the schedule being based on seasonal uses of agricultural chemicals and/or periods of inflow to the lake

Strategy 8: Conduct a survey to establish the extent and source of total and fecal coliforms that exceed the criteria

Strategy 9: Determine the applicability of additional management strategies for the following: 1) canals, using sediment removal and constructed wetlands, 2) marinas, using liquid waste management and boat maintenance control measures, and 3) establishing alternative, more appropriate, criterion for some parameters in order to prevent Class I/Class III water quality criteria for the tributaries from being exceeded

B. PHOSPHORUS LOADS AND TARGETS BY BASIN

The SFWMD Technical Publication 81-2 (Federico et al., 1981) developed a 40 percent phosphorus load reduction goal based on a modified Vollenweider model. This model, developed for Lake Okeechobee using data from 1973 to 1979, predicts the in-lake phosphorus concentration based on external loads, external flow, and turnover time (i.e., the amount of time it would take the lake to empty based solely on surface outflows). The agreement between model prediction and yearly average observed data was quite good for the 1973 to 1979 (**Figure 2-1**).

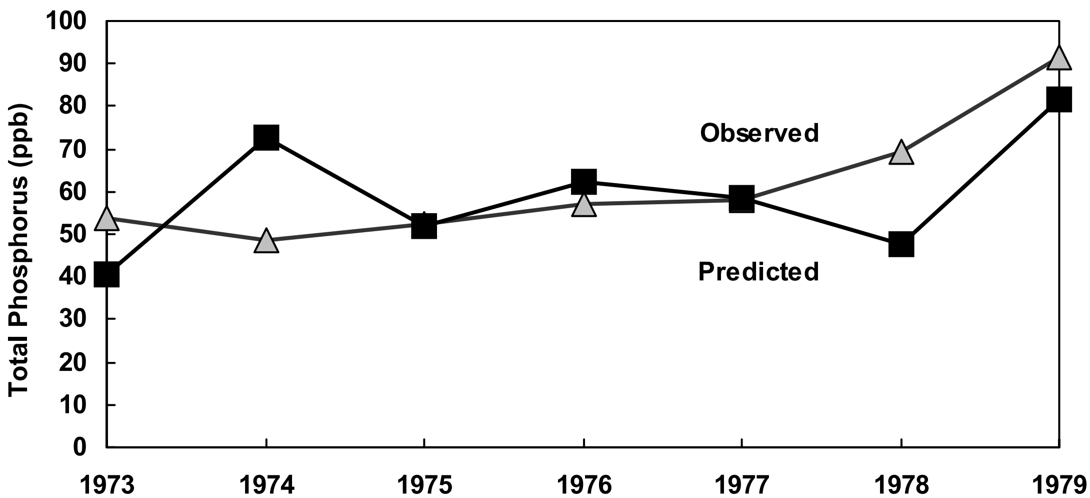

Figure 2-1. Comparison of the modified Vollenweider model total phosphorus predictions to observed data for 1973 to 1979

Given that the target in-lake phosphorus concentration and the TMDL is 40 ppb, the model can be rewritten to determine the phosphorus loads that would reach that target concentration. This loading goal, which averaged 397 tons per year, was used to set the criterion for each basin (**Figure 2-2**) by determining the flow-weighted average concentration of phosphorus that would result in 397 tons or less entering the lake. This value was 180 ppb at each inflow point. Thus, the 1989 *Interim Lake Okeechobee SWIM Plan* (SFWMD, 1989a) required that all tributary inflows to the lake should meet the 180 ppb performance limitation for total phosphorus or maintain their 1989 discharge concentration, whichever was less.

Targets are developed for each basin based on average annual, flow-weighted total phosphorus concentrations. These targets are adjusted for variations in discharge. To calculate the observed load from each basin, the observed concentration is multiplied by flow. Excess phosphorus loads are calculated as the difference between the observed and target loads. The phosphorus loads and targets for each basin for 1990 to 1994 and 1995 to 2000 are presented in **Tables 2-1** and **2-2**, respectively.

Figure 2-2. The drainage basins that contribute nutrient enriched runoff to Lake Okeechobee

Collectively, the flow-weighted mean concentration from controllable sources of these tributaries for the five-year period following full implementation of BMPs (1990 through 1994) was 243 ppb (**Table 2-1**). During this period, 19 basins were at least 10 percent above their target loads, and 8 basins were at least 10 percent below their target loads. The other 2 basins were within plus or minus 10 percent of their target loads. The excess loading was 140 tons per year based on target loads for each basin. The S65 basins (A through E) were not separated from each other because the measurements at these structures do not capture the seepage and bypass flows, which are significant. To determine the basin loads from S65A through S65E, the discharge out of S65 (Lake Kissimmee) was subtracted from the discharge from S65E. The resultant is assumed to be the contributions of flow and load from the S65A through S65E basins.

Table 2-1. Phosphorus (P) loads and targets by basin in the Lake Okeechobee watershed for 1990-1994

Basin	Area (square miles)	Target Total P (ppb)	1990-1994 Discharge (acre-feet)	Target Load (tons/ year)	Flow-Weighted Total P (ppb)	Average (tons/ year)	Over/ Under (tons/ year)	Percent Over/ Under Target
Controllable Sources								
715 Farms (Culvert 12A)	4	180	9,293	2.3	147	1.9	-0.4	-18%
C-40 Basin (S-72)	87	180	23,096	5.6	415	13.0	7.3	130%
C-41 Basin (S-71)	176	180	52,956	12.9	417	30.0	16.9	131%
S-84 Basin (C41A)	180	100	47,478	6.4	143	9.2	2.7	42%
S-308C (St. Lucie-C-44)	190	180	89,043	21.7	152	18.4	-3.3	-15%
East Beach DD (Culvert 10)	10	180	7,973	1.9	508	5.5	3.6	182%
East Shore DD (Culvert 12)	13	130	11,958	2.1	191	3.1	1.0	47%
Fisheating Creek	462	180	178,676	43.6	161	38.9	-4.7	-11%
Industrial Canal	23	180	22,210	5.4	110	3.3	-2.1	-39%
L-48 Basin (S-127)	32	180	13,267	3.2	246	4.4	1.2	37%
L-49 Basin (S-129)	19	180	8,595	2.1	133	1.6	-0.5	-26%
L-59E	15	160	4,512	1.2	245	1.5	0.6	49%
L-59W	15	160	5,867	1.6	163	1.3	0.0	2%
L-60E	6	100	877	0.1	194	0.2	0.1	55%
L-60W	6	100	298	0.1	247	0.1	0.0	36%
L-61E	22	90	4,805	0.7	153	1.0	0.5	63%
L-61W	22	90	7,308	1.1	101	1.0	0.1	12%
Taylor Creek/Nubbin Slough (S-191)	188	180	108,825	26.6	609	90.0	63.6	239%
S-131 Basin	11	150	7,965	1.6	103	1.1	-0.5	-31%
S-133 Basin	40	180	24,248	5.9	253	8.3	2.4	40%
S-135 Basin	28	160	21,557	4.7	98	2.9	-1.8	-39%
S-154 Basin	37	180	19,550	4.8	728	19.3	14.6	306%
S-2	166	160	31,424	6.8	231	9.8	3.0	44%
S-3	101	150	5,904	1.2	179	1.4	0.2	19%
S-4	66	180	17,766	4.3	175	4.2	-0.1	-3%
S-65A, B, C, D, E	749	113	265,192	55.9	257	92.4	35.6	64%
South Florida Conservancy DD (S-236)	15	90	3,407	0.4	116	0.5	0.1	29%
South Shore/South Bay DD (Culvert 4A)	7	80	7,195	0.8	113	1.21	0.4	54%
Nicodemus Slough (Culvert 5)	28	60	2,503	0.3	59	0.2	-0.1	-22%
Controllable Totals			1,003,746	226	243	366	140	62%
Uncontrollable Sources								
Rainfall		-	-			72.0		
S-65 (Lake Kissimmee)		-	733,505		38	39.3		
Lake Istokpoga (S-68)		-	183,872		29	7.2		
S-5A Basin (S-352-West Palm Beach Canal)		-	2,048		0			
East Caloosahatchee (S-77)		-	3,616		245	1.2		
L-8 Basin (Culvert 10a)		-	68,503		99	9.2		
Uncontrollable Totals			991,544			129		
Total Loading			1,995,291			495		
Target Loading (concentration-based)				355			140	39%
Vollenweider Target				399			96	24%

Table 2-2. Phosphorus (P) loads and targets by basin in the Lake Okeechobee watershed for 1995-2000

			1995-2000						Percent
Basin	**Area (square miles)**	**Target Total P (ppb)**	**Discharge (acre-feet)**	**Target Load (tons/ year)**	**Flow-Weighted Total P (ppb)**	**Average (tons/ year)**	**Over/ Under (tons/ year)**	**Percent Over/ Under Target**	**Change Over/ Under Target**
Controllable Sources									
715 Farms (Culvert 12A)	4	180	12,999	3.2	96	1.7	-1.5	-46.6%	-28%
C-40 Basin (S-72)	87	180	13,558	3.3	508	9.4	6.0	182.0%	52%
C-41 Basin (S-71)	176	180	46,001	11.3	429	26.8	15.5	138.1%	7%
S-84 Basin (C41A)	180	100	57,298	7.8	149	11.6	3.9	49.5%	7%
S-308C (St. Lucie-C-44)	190	180	34,134	8.4	185	8.6	0.3	3.0%	18%
East Beach DD (Culvert 10)	10	180	13,206	3.2	644	11.6	8.3	257.9%	75%
East Shore DD (Culvert 12)	13	130	14,439	2.6	164	3.2	0.7	26.0%	-21%
Fisheating Creek	462	180	210,576	51.5	178	50.9	-0.6	-1.2%	10%
Industrial Canal	23	180	20,672	5.1	103	2.9	-2.2	-43.1%	-4%
L-48 Basin (S-127)	32	180	26,457	6.5	230	8.3	1.8	27.7%	-9%
L-49 Basin (S-129)	19	180	14,630	3.6	91	1.8	-1.8	-49.3%	-23%
L-59E	15	160							
L-59W	15	160							
L-60E	6	100				No data available			
L-60W	6	100							
L-61E	22	90							
L-61W	22	90							
Taylor Creek/Nubbins Slough (S-191)	188	180	97,154	23.8	651	86.0	62.2	261.7%	22%
S-131 Basin	11	150	9,180	1.9	115	1.4	-0.4	-23.3%	8%
S-133 Basin	40	180	23,924	5.9	182	5.9	0.1	1.0%	-39%
S-135 Basin	28	160	22,845	5.0	116	3.6	-1.4	-27.4%	11%
S-154 Basin	37	180	26,602	6.5	826	29.9	23.4	358.9%	53%
S-2	166	160	29,235	6.4	197	7.8	1.5	22.9%	-21%
S-3	101	150	11,568	2.4	213	3.4	1.0	42.1%	23%
S-4	66	180	33,801	8.3	215	9.9	1.6	19.6%	22%
S-65A, B, C, D, E	749	113	283,267	43.4	213	81.9	38.5	88.7%	25%
South Florida Conservancy DD (S-236)	15	90	14,494	1.8	111	2.2	0.4	23.1%	-6%
South Shore/South Bay DD (Culvert 4A)	7	80	7,893	0.9	101	1.1	0.2	26.5%	-27%
Nicodemus Slough (Culvert 5)	28	60							
Controllable Totals			1,023,934	212	266	370	158	74.2%	12%
Uncontrollable Sources									
Rainfall		-	-			72.0			
S-65 (Lake Kissimmee)		-	885,858		84	100.3			
Lake Istokpoga (S-68)		-	292,451		59	23.3			
S-5A Basin (S-352-West Palm Beach Canal)		-	18		248	0.0			
East Caloosahatchee (S-77)		-	342		244	0.1			
L-8 Basin (Culvert 10a)		-	52,953		97	6.9			
Uncontrollable Totals			1,231,622		121	203			
Total Loading			2,255,556			573			
Target Loading (concentration-based)				415			158	37.9%	-2%
Vollenweider Target				371			201	54.3%	30%

The next six-year period, 1995 to 2000, the overall flow-weighted concentration from controllable sources increased slightly to 266 ppb (**Table 2-2**). Ten basins had concentrations at least 10 percent above their target and 6 basins had concentrations at least 10 percent below. Discharges for the L59, L60, and L61 basins, and Nicodemus Slough were not available for this period, and thus they were not included in this calculation. However, in the 1990 to 1994 period, they accounted for only 5.1 tons of phosphorus loads or less than 1.4 percent of the total.

The excess loading for the 1995 to 2000 period was 158 tons per year based on the flow and target concentrations for each basin (**Table 2-2**). This was a 2 percent decrease compared to the 1990 to 1994 period (**Table 2-1**). However, based on the Vollenweider model target, the excessive loading had increased by 30 percent compared to the 1990 to 1994 period. This is because the Vollenweider target includes both controlled and noncontrolled loads contributing to Lake Okeechobee.

The highest inflow concentrations were found in the S-154 and S-191 basins, where dairies are abundant and where the majority of the out-of-compliance WOD sites that are out of compliance are located. These basins, along with the S65 basins, account for most of the overtarget load, and, if they met their target concentrations, would collectively bring overall loading to Lake Okeechobee very close to the target. These basins currently receive intensive study, regulatory scrutiny, and are the focus of remediation activities. These basins are also the focus of the landowner-based initiative described later in this chapter. The Kissimmee River, which runs through the S65 basins, is currently being restored. As of this writing, the S65B structure has been removed and over seven miles of the C-38 canal has been plugged and fifteen miles of historic Kissimmee River have been reconnected.

Comparing noncontrollable loads in the two periods shows a disturbing trend. Subtracting out the atmospheric loads gives a noncontrollable load of 57 tons during the 1990 to 1994 period (**Table 2-1**), and 131 tons in the 1995 to 2000 period (**Table 2-2**). This large increase of 1995 noncontrollable surface discharges can only partially be explained by an increase in discharge. The flow-weighted average concentration of discharge from Lake Istokpoga and Lake Kissimmee more than doubled over this time period.

C. WATERSHED REGULATORY PROGRAMS

The *Surface Water Improvement and Management (SWIM) Plan - Update for Lake Okeechobee* (SFWMD, 1997a) published in 1997 discussed several programs that had already been implemented to achieve the phosphorus reduction in runoff from the watershed. A brief description of these programs and their current status is provided in this section.

C1. Dairy Rule

In June 1987, the Florida Department of Environmental Regulation, now known as the Florida Department of Environmental Protection (FDEP) enacted the Dairy Rule (Chapter 62-670, F.A.C.). The Dairy Rule required that all dairy operations within the Lake Okeechobee watershed and its tributaries implement BMPs for the purpose of reducing phosphorus inputs to the lake. A total of 49 dairies, the majority located in the Taylor Creek/Nubbins Slough and Lower Kissimmee River basins, came under jurisdiction of the rule.

The Dairy Rule did not establish a specific off-site phosphorus discharge concentration limitation, but required BMPs to be incorporated into the operation of dairies. These BMPs needed to provide reasonable assurances that each dairy could meet state water quality standards (Chapter 62-670, F.A.C.) and that acceptable phosphorus levels in off-farm discharges would be achieved (Albers et al., 1991). Although the *Interim Lake Okeechobee SWIM Plan* (SFWMD, 1989a) established a maximum discharge limitation of 1.2 mg/l total phosphorus, the dairies were exempted from permitting and enforcement under the WOD Program, since they were under the jurisdiction of the Dairy Rule.

Implementation of dairy BMPs was completed at 30 dairies. Four of these dairies have since closed, one of which was purchased by the District in 1994 with Save Our Rivers (SOR) funds and one was purchased for use as a reservoir assisted stormwater treatment area (RSTAS) that is part of a critical restoration project. Currently, only 26 dairies have operating permits of which 25 are active at this time. One dairy has temporarily closed while maintaining the Dairy Rule permit in an active status with the option of reopening at a later date. The FDEP continues to monitor the active dairies for compliance with their Dairy Rule operating permits. Nineteen dairies participate in the program.

C2. Works of the District/Regulation of Nondairy Land Uses

After the adoption of the *Interim Lake Okeechobee SWIM Plan* (SFWMD, 1989a), Chapter 40E-61, F.A.C., was developed by the SFWMD with an effective date of November 1989. The rule established criteria to ensure that use of, or connection to, a WOD project or lands would be compatible with the SFWMD's ability to carry out the water quality objectives found in several SFWMD programs, including those stated in Section 373.016, F.S.; Chapter 62-40, F.A.C.; and the SWIM Act as outlined in Sections 373.451 through 373.459, F.S., and Chapter 40E-61, F.A.C. This regulatory program applies to all nondairy land uses and areas of dairies not covered by the Dairy Rule that discharge to WOD projects or lands located within the Lake Okeechobee drainage basin.

Works of the District projects include waterways, canals, water control structures, rights-of-way, wetlands, remnant oxbows or slough, lakes, and streams that the District owns or has the responsibility of managing. All land uses within the basin are subject to this rule. However, the type of permit required depends on several factors: the type of land use, the extent to which the use is a contributor of phosphorus to the lake, and the basin in which the land is located. The deadlines for submittal of permit applications were prioritized to bring the most problematic basins into compliance first.

From January 1990 through March 2001, 721 permits were issued in the following basins: S-191, S-154, S-127, C-38 Pool E, S-4, S-71, S-72, Industrial Canal, S-133, Culvert 10 (East Beach Drainage District), C-38 Pool D, Culvert 12A (715 Farms), Fisheating Creek, and S-154C. In all of the 14 priority basins, initial permitting of all problematic parcels equal to or greater than five acres in size is complete. Administrative maintenance of the permit files is an ongoing activity, as land use and ownership changes require permit modifications and transfers.

In priority basins, individual permits were required for certain land uses and general (Notice of Intent) permits were required for other land uses. All other basins required a general (no Notice of Intent) permit. Provided in **Table 2-3** is a simplified overview of the various land uses and the type of permit required by the SFWMD. In the basins north of the lake, the primary nondairy land uses are improved pasture for beef cattle and agricultural uses such as sod production.

Table 2-3. Works of the District permits required for various land uses

General Permit (Notice of Intent)	Individual Permit
Urban stormwater Golf courses Sugarcane Horse farms Nurseries Land spreading of sludge Sod farms	Dairy land use not covered by Dairy Rule Improved pasture Vegetable farms/row crops Heifer farms Poultry farms Hog farms Goat farms

In the regulatory program, users of the WOD are required to meet specific off-site phosphorus discharge concentration limitations. If the SFWMD monitoring data indicate that the probability of the average annual off-site discharge concentration not being met is greater than 50 percent, the affected landowner is required to take corrective measures to bring discharges from the property into compliance with the rule. The SFWMD conducts a two-pronged water quality monitoring program to identify high phosphorus source areas within the basin and to distinguish between landowners who are in compliance and those who are not. Routine biweekly water quality monitoring is conducted on permitted parcels. At least one year of monitoring is required on all individual permits to document compliance status. Unfortunately, due to limited resources it has not always been possible to monitor all individual permits. In some cases monitoring conducted downstream of several permit holders has been used to establish compliance. A nonroutine, site specific surveillance monitoring program is also conducted throughout the basin to identify high phosphorus source areas in both the priority and nonpriority basins.

A formal notification of potential noncompliance is sent to owners of parcels discharging surface waters with high phosphorus concentrations. Once noncompliance is confirmed, a permittee is required to develop a nutrient management plan with an implementation schedule. This plan is incorporated into their SWIM permit as a permit addendum modification (PAM). If SWIM phosphorus limitations are not achieved within one year of issuance of the PAM, additional BMPs and corrective actions may be required. The effectiveness of identified corrective actions are evaluated using existing water quality and soils data along with the field-scale Everglades Agricultural Area Model (EAAMOD). This information is then documented in a formal technical assessment and initiated through a consent agreement between the SFWMD and the landowner.

The following list includes BMPs incorporated into the nutrient management plans for the WOD sites that are out of compliance:

- Remove residual phosphorus in soils in former high-intensity areas (HIAs) through a nutrient management program of forage production (sorghum, oats, and Bahia, Alicia Bermuda, and improved grasses) with subsequent harvest and export
- Develop grassed buffer areas around existing areas where animals congregate
- Minimize or eliminate the development of new animal congregating areas by mobilizing shade, water, and feeding areas and placing these areas away from tributaries in well drained, sandy areas
- Eliminate cattle from tributaries and develop rotational grazing strategies that move cattle away from sensitive areas during the peak rainfall periods
- Eliminate phosphorus fertilizer applications near tributaries
- Limit the overdrainage of wetland soils
- Restore wetlands that have been ditched or drained
- Reduce animal density (voluntary)
- Reduce phosphorus import in animal feeds
- Use soil amendments to improve soil binding capacity and enhance availability of phosphorus for plant uptake
- Use the University of Florida’s Institute of Food and Agricultural Sciences (IFAS) soil testing data and subsequent fertilizer application recommendations to optimize plant growth and minimize nutrient runoff
- Eliminate off-site discharge from areas that have a high density of animals
- Scrape sediment and remove from the site or spread in upland areas
- Use a combination of chemical and biological treatment of hot spot ditches

- When maintaining ditches, remove and spread sediments in upland areas
- Drag and spread manure to reduce the accumulation of manure in high traffic areas to distribute nutrients more evenly across the pastures
- Develop balanced phosphorus budgets as part of a nutrient management plan

As of March 2001, the WOD noncompliance activity summary included 28 PAMs and 8 Consent Agreements. Sixteen permittees that have initiated corrective actions have achieved the SWIM phosphorus limitation for their respective land use. Fourteen of the permittees that have developed corrective actions in accordance with their PAM have since achieved their off-site phosphorus limitation. The remaining two permittees have achieved compliance following the implementation of corrective actions called for in their Consent Agreement.

D. COMPREHENSIVE EVERGLADES RESTORATION PLAN

The Central and Southern Florida Project Comprehensive Review Study, Final Integrated Feasibility Report and Programmatic Environmental Impact Statement (USACE and SFWMD, 1999) recommended a comprehensive plan for the restoration, protection, and preservation of the water resources of Central and South Florida, including the Everglades ecosystem, while providing for the other water-related needs of the region. The comprehensive review study, referred to as the Restudy, proposed project components and determined their potential impacts on existing resources. The Florida Legislature passed the Restudy Bill (Senate Bill 1672) in April 1999, and authorized the SFWMD to be the local sponsor of these projects. The Restudy projects are being implemented through the Comprehensive Everglades Restoration Plan (CERP). The CERP contains over 60 major components that involve either structural or operational changes to the existing C&SF Project. The basic approach of the plan is to capture most of the 1.7 billion gallons of water per day that on average is discharged through project canals to the Atlantic Ocean and the Gulf of Mexico and use it to supplement water supply and to achieve the restoration of natural systems, including Lake Okeechobee and the Everglades. Restoration of natural areas will be accomplished by restoring more natural flows of water, improving water quality, and establishing more natural hydroperiods.

Major features of the CERP that directly affect the Lake Okeechobee watershed include the following:

- Taylor Creek/Nubbin Slough Reservoir-Assisted Storage Treatment Area: a 5,000-acre storage area with a 5,000-acre water treatment area
- North of Lake Okeechobee Storage Reservoir: a 17,500-acre storage area with a 2,500-acre water treatment area
- Lake Okeechobee Water Quality Treatment facilities: a 1,775-acre treatment area in the S-154 Basin; a 2,600-acre treatment area in the

S-65D Basin; and plugged drainage ditches that will result in the restoration of 3,500 acres of wetlands

- Lake Okeechobee Tributary Sediment Control: capturing or removing phosphorus-laden sediment in tributaries to prevent it from reaching Lake Okeechobee
- Lake Okeechobee Aquifer Storage and Recovery (ASR): a series of ASR wells around the lake with 1 billion gallons per day capacity to be proceeded by pilot testing

E. CURRENT MANAGEMENT PROGRAMS

Effective phosphorus control strategies can only be successfully implemented if we understand the source and fate of phosphorus in uplands, wetlands, and streams of the watershed. To achieve this understanding, several research projects were conducted to develop the understanding of the movement of phosphorus in the watershed. Completed and ongoing research projects are described in this section. Key results presented here have implications for the development of cost-effective and sustainable BMPs to reduce phosphorus loads from the watershed into adjacent aquatic systems.

E1. Phosphorus Budgets

Phosphorus is of particular concern in this system because it has been identified as the key element that contributes to the eutrophication of the lake (Davis and Marshall, 1975; Federico et al., 1981). Early research indicated that phosphorus loads originated from agricultural nonpoint sources, mainly beef cattle ranches and dairy farms (Boggess et al. 1995). Based on data from 1985 to 1989, Boggess et al. (1995) estimated that the total phosphorus import into 22 basins of the northern Lake Okeechobee watershed was approximately 3,500 tons per year. The phosphorus import was primarily in the form of pasture fertilizer and dairy feed. In addition, approximately 330 tons of phosphorus entered the watershed in the form of rain. The total phosphorus export in milk, cows, and crops was about 900 tons per year. In addition, about 330 tons of phosphorus reached the lake per year. From these values, it was estimated that the net phosphorus import of 2,600 tons per year was retained in upland soils and the transport system (streams and wetlands). This imbalance in import versus export continues to add to the build-up of phosphorus in the northern Lake Okeechobee watershed. This has caused the concern that unless controls are placed on importing phosphorus, attempts to restore Lake Okeechobee will be delayed or fail altogether.

The study by Boggess et al. (1995) was based on phosphorus and materials budget information collected ten years ago, which is prior to the implementation of many BMP programs. Since then, land uses and associated management practices have changed dramatically. A study is being conducted to update the phosphorus budget information, taking into account many of the land management changes that have occurred in recent years. This new phosphorus budget will use the most recent phosphorus import and export data available, as well as examine phosphorus sources that were not explored previously, such as sludge application, poultry manure, on-site septic systems, and phosphorus discharges via subsurface flow. This study also includes analyzing possible relationships between net phosphorus imports and basin characteristics (land use type, soil type, stream type, etc.) for each basin, identifying basin characteristics that affect net phosphorus imports and storage, and developing a graphical user interface to view input data (farms, drainage basins, hydrographic features, land uses, and soil types) and phosphorus budget results (import and export) using ArcView™, a geographic information system. The updated phosphorus budget information will be available in March 2002. The final report and the graphical user interface are due in April 2002. Based on this information, we will determine how much the net import of phosphorus to the watershed has changed over the past decade, and what sources are particularly problematic. Then, we can target those problem sources and determine effective means to control them.

E2. Phosphorus Assimilation

The WOD Rule limits total phosphorus concentrations in runoff leaving land parcels (SFWMD, 1989a). The total phosphorus concentration limitations range from 0.18 to 1.2 mg/l. These limitations were developed based on estimated phosphorus assimilation in channels and wetlands along measured flow paths. A first order exponential decay function was used to describe phosphorus assimilation with flow travel distance in channels and wetlands (SFWMD, 1989a). However, the assimilation of phosphorus is actually influenced by diverse physical, chemical, and biological factors. These factors include phosphorus sorption/desorption by sediments, water flow rate and travel length, and phosphorus uptake by vegetation. If phosphorus load estimates from the watershed are to improve, it will be necessary to develop better phosphorus retention/assimilation algorithms for describing phosphorus transport dynamics. These algorithms are critical to watershed nutrient management.

A second order exponential decay function was used in the updated Lake Okeechobee Agricultural Decision Support System (LOADSS) model. The function included a temporal adjustment of flow rate on an annual scale (SWET, 1999). To take into account of additional biogeochemical processes within various flow conveyance systems (e.g., overland, channels, natural streams, and wetlands), a study was conducted recently to enhance the existing algorithm used in the LOADSS model. After examining the available data, the contractor concluded that the data resources for the Lake Okeechobee watershed are insufficient to advance the current phosphorus assimilation algorithm. Therefore, the focus of future studies should be gathering the necessary data to properly quantify the phosphorus assimilation in specific water conveyance systems.

E3. Potential Phosphorus Load Reduction from Nondairy Out-of-Compliance Sites and Dairy Hot Spots

E3a. Beef Cattle Waste

Cattle waste from the basins north of Lake Okeechobee has been identified as a source of phosphorus contributing to the accelerated eutrophication of the lake. The WOD program issues permits and monitors phosphorus concentrations in surface runoff from nondairy land parcels that are 0.5 acres or greater in size. A site is considered out of compliance if the average total phosphorous concentration in the runoff within a 12-month period exceeds the regulatory standard for the site. Pasture sites with excess phosphorus discharge are potential targets for corrective management actions designed to reduce phosphorus loads.

Zhang et al. (2001) indicates that, from October 1998 to September 1999, 77 out-of-compliance sites discharged an estimated 51 tons of phosphorous on an average annual basis, of which an estimated 24 tons per year reached Lake Okeechobee. The remaining estimated 27 tons of phosphorus load were retained by streams and wetlands. An estimated 16 tons of phosphorus load reduction per year would be expected if phosphorus concentrations in runoff from these sites do not exceed the discharge limits. If the land uses were changed to native range land with an off-site annual total phosphorus areal loading rate of 0.102 pound per acre, an estimated 23 tons of phosphorus load reduction would be expected on an average annual basis from these out-of-compliance sites.

Of the 77 out-of-compliance sites, 12 sites had a phosphorus loading rate greater than 2.5 pounds per acre. These sites were recommended to be placed on the priority list for the Lake Okeechobee Water Retention/Phosphorus Removal Critical Restoration Project. Ongoing research is being conducted by the District to identify remedies and associated costs for these sites and to evaluate the cost-effectiveness of strategies for reducing phosphorus loads.

E3b. Dairy Waste

Dairy waste from the northern Lake Okeechobee watershed has been identified as a source of phosphorus contributing to the accelerated eutrophication of Lake Okeechobee (Ray and Zhang, 2001). Sites were identified as priority sites if the average total phosphorus concentration in runoff exceeded regulatory site limitations from October 1998 to September 1999. These sites are located at both active and former dairies. The phosphorus discharge limit for active dairy sites is 1.2 mg/l. The discharge limitations for former dairy sites vary based on current land use and must not exceed 1.2 mg/l. Twenty-one priority sites were identified within the northern Lake Okeechobee watershed. These sites produce an estimated 18.1 tons of phosphorus load annually, of which an average of 9.5 tons of phosphorus load reaches the lake on an annual basis. The remaining 8.6 tons of phosphorus load were retained/assimilated by streams and wetlands in the discharge transport system between the sites and the lake. If none of the sites were to exceed the 1.2 mg/l phosphorous runoff concentration, off-site loads would be reduced by an estimated 10.7 tons, with the loads to the lake reduced by 5.8 tons. Furthermore, if all dairy sites were converted to improved pasture with a discharge concentration limitation of 0.35 mg/l, off-site loads would be reduced by an estimated 15.7 tons and loads to the lake would be reduced by 8.3 tons.

These load estimates do not include the outer pastures associated with the dairies. In 1999, three monitoring stations were added to the discharge points of the dairy pastures. This information will be used to calibrate a computer simulation model that will estimate the phosphorous load from all dairy pastures. This information will be included in the updated study. Due to the 2000 drought, not enough samples were collected to complete this study by the original target date of December 2001. The study will be extended until an adequate number of samples have been collected and analyzed.

E4. Modeling Efforts

To determine the effectiveness of individual BMPs, a systematic methodology for cross-comparison of alternative strategies for phosphorus load reduction, including field-scale, farm-scale, or basin-scale phosphorus reduction practices, needed to be developed. The need to evaluate practices at different scales resulted in the development of field- and basin-scale computer models. Projects include development and application of the following models: (1) the EAA model upgrade; (2) the next generation field-scale Nonpoint Source Pollution Model; (3) the next generation Watershed Phosphorus Transport Model; and (4) the Lake Okeechobee Agricultural Decision Support System. General overviews and applications of each project are presented below.

E4a. EAA Model Upgrade

A field hydrologic and nutrient transport model (FHANTM) (Tremwel and Campbell, 1992), has been used in the Lake Okeechobee watershed as a tool to evaluate the effectiveness of BMPs implemented on parcels out of compliance with the WOD phosphorus discharge concentration limitations (Gornak and Zhang, 1999). Unfortunately, FHANTM does not handle the phosphorus soil interaction well. Zhang and Gornak (1999) evaluated three field-scale models, FHANTM, FHANTM 2.0, and the EAA Model (EAAMOD), to determine which was best suited for use in the WOD program. It was concluded that none of the models were sufficient, but that EAAMOD had the most potential. Therefore, EAAMOD was upgraded in 2000 for use in the Lake Okeechobee WOD program.

In addition to upgrading the field-scale version of EAAMOD, the field-scale model is to be integrated into a farm-scale model (EAAMOD WAMView). A field-scale model evaluates the land use from one pasture. The advantage of the farm-scale model is that an entire farm can be simulated at one time rather than simulating the fields individually. Final adjustments to the farm-scale model are being made at this time.

E4b. Nonpoint Source Pollution Model

Runoff from fields in the Lake Okeechobee watershed is a major source of phosphorus entering the lake. The ability to estimate edge-of-field phosphorus loads and potential load reductions due to BMPs is important to programs whose goal is to limit the amount of phosphorus entering the lake. Examples of such programs are WOD, isolated wetland restoration, and reservoir-assisted STAs. The Nonpoint Source Pollution Model estimates the impacts that land use practices and BMPs have on reducing phosphorus loads leaving a field.

The Nonpoint Source Pollution Model has hydrology and nutrient transport components and a graphical user interface. The hydrology component computes overland and ground water flows leaving a field. The nutrient transport component computes phosphorus concentrations in these flows, and can be expanded to include nitrogen should the need arise. The graphical user interface facilitates use of the model by automating many modeling functions including input data preparation, model execution, and output analysis. The Nonpoint Source Pollution Model also will be a component of the basin-scale Phosphorus Transport Model.

E4c. Phosphorus Transport Model

The Phosphorus Transport Model was originally developed and applied to the Taylor Creek basin (Zhang et al., 1996). It gave close estimates of flow and phosphorus loading on a seasonal basis. The next generation of the Phosphorus Transport Model operates on a daily time step and it contains two submodels: a field-scale submodel and a channel system submodel. The field-scale submodel will simulate phosphorus loads leaving individual fields in a watershed and is being developed by the Next Generation Field-Scale Nonpoint Source Pollution Model project. The channel system submodel will receive runoff and phosphorus loads leaving fields as input and simulate phosphorus transport and removal by streams, canals, and wetlands. The channel system submodel will have a hydrology component to simulate water movement, and a transport component to simulate phosphorus transport and removal. Also, a graphical user interface will be developed to facilitate model use by automating many modeling functions, including input data preparation, model execution, and output analysis. The Phosphorus Transport Model can be used to evaluate the effectiveness of BMPs on reducing phosphorus loads from the watershed to the lake. The final product is due in July 2003.

E4d. Lake Okeechobee Agriculture Decision Support System

The Lake Okeechobee Agriculture Decision Support System (LOADSS) is a tool based on a geographic information system that evaluates the effects of different land use practices on reducing phosphorus loads and the economic impact of these practices on the surrounding area (Negahban et al., 1995). LOADSS was originally developed with data collected before 1987. The model was updated in 1997 with 1995 conditions (SWET, 1999).

The updated LOADSS model contains the most current land use data and economic information. Land parcel boundaries developed for the WOD rule also were incorporated into the LOADSS database. The update created a new database allowing users to conduct a phosphorus loading analysis at a finer spatial scale. The updated economics database included the cost of converting one land use to another. Within LOADSS, a land use and phosphorus management plan can be developed using a menu-driven user interface. The updated LOADSS model allows the District to evaluate what-if scenarios and determine the effectiveness of phosphorous control practices on reducing phosphorus loads to the lake.

E5. Optimization of BMPs for Beef Cattle Ranching in the Lake Okeechobee Basin

Research on optimizing BMPs for beef cattle ranching in the Lake Okeechobee basin was initiated in 1996 to reduce nonpoint sources of phosphorus pollution for beef cattle and contribute to modeling efforts for load reduction scenarios. The project is being implemented in several phases, and it is expected to be concluded in 2005. The first phase examines cattle stocking density BMPs.

This project was established within the broader context of a Memorandum of Understanding among the SFWMD, Archbold Expeditions' MacArthur Agro-Ecology Research Center, the IFAS, and the Florida Cattleman's Association. The program was established at MacArthur Agro-Ecology Research Center, a 4,170-hectare cattle ranch operated by Archbold Expeditions in the C-41 basin along Harney Pond Canal. In addition to financial support from the SFWMD, the cattle stocking rate project has received funding from Archbold Biological Station, the IFAS, the FDEP/USEPA 319 funds, and the United States Department of Agriculture's Natural Resources Conservation Service (NRCS) and the National Research Initiative to support a multifaceted project to examine the ecology and economics of sustainable cow-calf operations and control of phosphorus in surface runoff.

The most significant finding of the project to date is that surface water phosphorus concentrations and total phosphorus loads were significantly greater from the improved pastures than from the semi-native pastures. Total phosphorus concentrations and loads were five times higher on the improved pastures than on the semi-native pastures. This difference could be an artifact of prior land use history, since the improved pastures used in the study received phosphorus inputs for many years up until 1986. The semi-native pastures, by contrast, were never fertilized. Additionally, a notable difference was observed in the proportion of ortho-phosphorus in the runoff from the two pasture types. The ratio of ortho-phosphorus to total phosphorus was 0.74 in the improved pastures and 0.23 in the semi-native pastures. The improved pastures not only exported more phosphorus but they also exported a more biologically available form of phosphorus.

Soil phosphorus test results were consistent with the surface water phosphorus data from the pastures. The high phosphorus content in the improved pasture runoff water was matched by correspondingly high water soluble phosphorus concentrations in the improved pasture soils, which were greatest in the upper 5 centimeters of the soil. Links between soil phosphorus pools and surface water concentrations warrant further investigation.

This project is scheduled to continue through 2005. Statistical differences resulting from the different stocking rates are not expected to be evident this early in the project. The stocking density treatments need to be continued for at least two more years before assessing whether the cattle stocking densities being tested have an appreciable effect on nutrient concentrations or loads in surface runoff. In addition to continuing the study to obtain statistical differences in stocking rates, variability in annual rainfall necessitates that the project be continued to capture the range of loading scenarios likely to be encountered from beef cattle pastures in the basin.

E6. Star Grass Experiment

Rechcigl et al. (1990) and Rechcigl and Bottcher (1992) showed that fertilization of Bahia grass can contribute to phosphorus in runoff because the Bahia grass does not require additional phosphorus. As a result of those studies, which were funded by the SFWMD, the IFAS reduced the phosphorus fertilization requirement for Bahia grass to zero for South Florida. This was a win-win scenario for the ranchers and Lake Okeechobee. Ranchers will not need to pay for costly phosphorus fertilizer that is not needed and less phosphorus is imported to the Lake Okeechobee watershed.

As a follow up to the Bahia grass study, the IFAS suggested that phosphorus fertilization recommendations for other pasture grasses may also be reduced. A major field and laboratory experiment was initiated in 1998 to evaluate the optimum phosphorus fertilization requirements for star grass and to evaluate the use of limestone and gypsum soil amendments to reduce the mobility of phosphorus. This study is being conducted by IFAS on the Williamson Ranch in Okeechobee County.

Two years of data have been collected from samples of runoff and ground water from field plots and samples of leachate from soil columns in the laboratory. Preliminary data indicate that both calcium limestone and gypsum may retard phosphorus movement in ground water but not in surface water. The initial data also indicate that the phosphorus fertilization recommendations for star grass may be reduced. Unfortunately, due to the drought conditions in 2000, only two small runoff events occurred.

One field and educational day has been conducted to present the preliminary results of the experiment to the local ranchers. Two more field and educational days are scheduled to be conducted over the next two years. The final report is due in September 2002. An IFAS extension publication will also be produced to provide ranchers with the results of the study.

F. LAKE OKEECHOBEE PROTECTION PROGRAM AND PERMITS

The Florida Legislature passed the Lake Okeechobee Protection Program, amending Section 373.4595(3), F.S., during the 2000 session. This law establishes a comprehensive long-term program to restore and protect Lake Okeechobee and its downstream receiving waters. The legislature also appropriated $38.5 million dollars to expedite the restoration of Lake Okeechobee. It requires significant involvement and cooperation between the FDEP, the FDACS, the SFWMD, the IFAS, and the NRCS to implement the program. The legislation is similar in scope and approach to the Everglades Forever Act, involving major new programs in planning, construction of major public treatment projects, and new BMP and permitting requirements, though it does not include dedicated funding. It establishes the Lake Okeechobee Protection Program and authorizes Lake Okeechobee Protection Permits (Section 373.4595(4), F.S.).

F1. Overview of the Lake Okeechobee Protection Program

The Lake Okeechobee Protection Program contains several components:

Lake Okeechobee Protection Plan. By January 1, 2004, the SFWMD, in cooperation with the FDEP and the FDACS, is to complete the Lake Okeechobee Protection Plan. This plan will determine how water quality standards, particularly for phosphorus, will be met in Lake Okeechobee and its downstream receiving waters. The plan include a combination of source controls (e.g., BMPs) and treatment facilities that will be constructed by the District and its partners. It may also determine how sediments within the lake will be managed. The components of this plan are discussed later in this chapter.

Lake Okeechobee Watershed Phosphorus Control Program. The Lake Okeechobee Watershed Phosphorus Control Program includes both agricultural and nonagricultural BMP projects. In February 2001, the FDEP, the FDACS, and the SFWMD entered into an interagency agreement to address how to implement the programs and coordinate with existing regulatory programs (e.g., WOD and Everglades restoration programs). According to the agreement, the FDACS will be responsible for establishing BMPs for agriculture. If water quality problems persist on farms where BMPs have been implemented, the FDACS shall reevaluate the BMPs and make appropriate changes to the rule to adopt additional BMPs. Development of nonagricultural nonpoint source BMPs will be the responsibility of the FDEP. The FDEP shall initially focus on the priority basins, and will deal with appropriate nutrient applications rates for soil amendments, monitoring to assess the effectiveness of BMPs including domestic wastewater systems, land application of animal residuals, and alternative nutrient reduction technologies.

Lake Okeechobee Construction Project. The Lake Okeechobee Construction Project will be implemented in two phases. In Phase 1, a series of projects will be constructed that are focused in the priority basins (S-191, S-154, S-65D, and S-65E) and are consistent with the Lake Okeechobee Issue Team's Action Plan (Harvey and Havens 1999). These include construction of two pilot STAs and the restoration of several isolated wetlands as part of the Lake Okeechobee Critical Project, a joint program between the SFWMD and the USACE, a sediment removal pilot project in a tributary draining into Lake Okeechobee, and design work on a large-scale STA in the S-191 basin. In Phase 2, the District, in cooperation with the other agencies, will develop an implementation plan for the construction of additional facilities to further reduce phosphorus loading throughout the watershed.

Lake Okeechobee Research and Water Quality Monitoring Program. The SFWMD, in cooperation with the FDEP and the FDACS, is to complete an extensive research and monitoring program that will provide the necessary information for the Lake Okeechobee Protection Plan. A water quality baseline for total phosphorus will be conducted to record existing conditions. Monitoring will be conducted for long-term ecological changes and for compliance with water quality standards. Other specifically identified components include 1) development of a Lake Okeechobee water quality model, 2) determination of phosphorus sources within the watershed, 3) assessment of phosphorus sources from the Upper Kissimmee Chain-of-Lakes and Lake Istokpoga, 4) assessment of water management practices within the watershed, and 5) evaluation of the feasibility of alternative nutrient reduction technologies.

Exotic Species Control Plan. The District, with cooperation from the FDEP and the FDACS, has identified the exotic species within the Lake Okeechobee watershed. The Exotic Species Control Plan was developed to protect the native flora and fauna from the invasion of exotic species.

Lake Okeechobee Internal Phosphorus Management Program. By July 1, 2003, the District, in cooperation with the FDEP and the FDACS, is to complete a feasibility study to determine it if is reasonable to manage phosphorus-laden sediments in the lake. If feasible, the District will establish the Lake Okeechobee Internal Phosphorus Management Program. Through this program the District will pursue the design, funding, and permitting for implementing sediment management methods.

Annual Progress Report. The District is to submit an annual progress report on the implementation of the Lake Okeechobee Protection Program to the Governor of Florida and the Florida Legislature. The second one will be submitted on January 1, 2002.

F2. Overview of the Lake Okeechobee Protection Permits

The Lake Okeechobee Protection Permits contains several components:

Existing Structures. All structures discharging into Lake Okeechobee are to have an FDEP permit, and discharges from the SFWMD structures are to achieve state water quality standards by January 1, 2015. The SFWMD is not to divert waters to the St. Lucie River, Caloosahatchee River, or the Everglades, in such a way that state water quality standards are violated, unless the SFWMD declares an emergency and FDEP concurs (existing law retained).

Lake Okeechobee Construction Project Facilities. The SFWMD is to obtain permits from the FDEP for the Lake Okeechobee Construction Project. The design objective is to meet the 40 ppb target for phosphorus by 2015, unless the TMDL for the water body is different.

F3. Lake Okeechobee Watershed Phosphorus Control Program

Several projects are being conducted within the Lake Okeechobee Watershed Phosphorus Control Program. They include the previously mentioned star grass experiment to determine the appropriate application rates for soil amendments; a study on the land application of residuals and chicken manure; a project to identify, select, monitor, and implement best available technologies (BATs) for dairies; isolated wetland restoration; and the Phosphorus Source Control Grant Program.

F3a. Land Application of Residuals and Chicken Manure

Although dairy farming and beef cattle ranching are often cited as the main source of phosphorus input to the lake, the contribution from other sources outside the watershed, such as the land application of sewage sludge (residuals) and chicken manure, also contribute phosphorus to the lake. In Florida, 66 percent of the residuals are applied to land (FDEP, 1997). In 1998, residuals and chicken manure contributed 1,259 dry tons of phosphorus loading to the Lake Okeechobee watershed (FDEP, 1999).

Beneficial use of residuals and chicken manure via land application is usually limited by nitrogen considerations. Customarily, residuals application rates are based on nitrogen needs of the crop. This practice often results in phosphorus inputs that far exceed the amounts required for normal growth. Addition of phosphorus beyond plant utilization is a waste of a nutrient resource, and in areas of sandy soils, could pose an environmental liability. To reduce phosphorus runoff, the FDEP has initiated a phosphorus rule in the basin, limiting residual application to the phosphorus requirement of the crop versus the nitrogen requirement.

Soils in the Lake Okeechobee watershed present a unique situation for management of phosphorus in applied wastes due to a fluctuating water table and predominantly sandy soils with low phosphorus retention capacity. These conditions promote transport of phosphorus via surface runoff and subsurface lateral seepage to streams and canals, which can lead to eutrophication of surface waters.

Water treatment residuals containing aluminum are frequently disposed in landfills. During land application, addition of aluminum to wastewater residuals and chicken manure may bind excess phosphorus, thereby minimizing the threat to surface waters.

The Lake Okeechobee Action Plan (Harvey and Havens, 1999) recommends enhanced source control as a factor in evaluation of the watershed phosphorus loading issue. In addition, the Lake Okeechobee Protection Act (Section 373.4595, F.S.) requires entities within the Lake Okeechobee watershed to develop conservation or nutrient management plans that limit domestic wastewater residual application, based upon phosphorus loading.

In support of these directives, the District and the FDEP initiated a project that will help ensure that associated nutrient management plans are based on sound science. The results from this study will identify any environmental and health problems associated with use of residuals and chicken manure in the watershed. Results will include recommendations regarding judicious applications of residuals and chicken manure and their establishment as a BMP for landowners in the watershed. At the time of this writing, the laboratory characterization of the waste materials and construction of the field study is currently under way. Monitoring activities are scheduled to commence in 2002. The final report is due by the end of 2003.

F3b. Dairy Best Available Technologies

In the previous Lake Okeechobee SWIM Plan (1997) it was noted that numerous dairies have runoff with total phosphorus concentrations in excess of 1,000 ppb, and that current monitoring data show some sites have concentrations above 7,000 ppb. At the present time, many of the 20 active dairies within the priority basins have phosphorus discharge concentrations in excess of the 1,200 ppb limit identified in the WOD Program (Chapter 40E-61, F.A.C.). Given the current level of water quality in the runoff from the Lake Okeechobee watershed, a comprehensive project is being undertaken to identify, select, and implement best available technologies (BATs) that will significantly reduce the export of phosphorus from dairy operations into tributaries and Lake Okeechobee.

The objectives of this project will be to identify, select, monitor, and implement BATs that will significantly reduce the export of phosphorus from dairy operations into Lake Okeechobee and its tributaries. Various alternatives will be evaluated to determine the best comprehensive system of technologies that will address the multiple dairy farm components (HIAs, waste management system, pastures, etc.). Selection of technologies for implementation will be accomplished by an objective methodology that allows for review and input by a multiagency team composed of the FDEP, the FDACs, the NRCS, the SFWMD, and stakeholders. This project will address, at a minimum, the following issues:

- Engineering feasibility of proposed alternatives
- Short- and long-term costs (e.g., capital, start-up, cost per kilograms phosphorus removed, operation and maintenance) including potential revenue sources to offset project costs
- Feasibility of each alternative relative to obtaining a water quality goal of 40 ppb (Note that a numeric goal is necessary for the comparison of alternatives. A goal of 40 ppb has been selected for this project based on the most recent regulatory requirements for the watershed and to reduce the harmful ecological impacts to the lake and downstream regional water resources. If this goal is not attainable, the selected consultant will identify the level of phosphorus reduction that is technically and economically practicable.)
- Process start-up time and a time line to achieve desired treatment goals
- Socioeconomic implications (i.e., economic impacts, cultural resources, social benefit/cost factors, etc.)
- Legal and permitting issues
- Coordination with other agencies to avoid duplication of efforts
- Opportunities for partnerships with the private sector

It is recognized that in a comprehensive approach to reducing phosphorus export from dairies, different scenarios may be required for individual dairy phosphorus reduction plans. For example, one dairy's phosphorus export problem may be primarily due to limitations in its existing waste management system, while another dairy's problems may have arisen as a result of residual phosphorus accumulation in its outer pasture areas. Phosphorus reduction might be accomplished on each of these dairies using different technologies or combinations of those technologies. For this reason, a comprehensive nutrient management plan is being developed for each of the three dairies participating in this project prior to selecting appropriate technologies. Each dairy phosphorus reduction scenario is likely to affect project costs, the nature and magnitude of phosphorus export, and/or other important considerations.

A specific set of goals and performance measures for each of the alternatives have been developed through this project. Each technology will be evaluated against the performance measures to identify all feasible alternatives for reducing phosphorus exports from the dairies. All of the potential impacts (environmental, socioeconomic, etc.) of each alternative will also be identified. Information regarding the technologies that are selected for implementation on the three dairies participating in this project will be disseminated to the other dairies and ranches in the watershed. The assessment phase of the project was completed in 2001. The Governing Board approved the project proceeding into the implementation phase. Installation of a water quality monitoring network has been initiated and design and construction of the technology will follow thereafter.

F3c. Lake Okeechobee Water Retention/Phosphorus Removal Critical Restoration Project

In 1996, the South Florida Ecosystem Restoration Working Group initiated critical restoration projects to be implemented under the USACE's authority provided in Section 528 of the 1996 Water Resources Development Act. In 1998, the USACE and the SFWMD proposed the Lake Okeechobee Water Retention/Phosphorus Removal Critical Restoration Project to the working group. The working group ranked this project number ten on the list of critical restoration projects. A cooperation agreement for this project was signed on January 7, 2000. The project was estimated to cost $16,360,000. The SFWMD is the local sponsor of the project, which will be cost shared between with the USACE and the SFWMD.

The initial vision of this project was to increase regional water storage north of Lake Okeechobee through wetland restoration/creation on lands volunteered by private landowners. Approximately 45 percent of the wetlands in the Lake Okeechobee watershed have been ditched in order to speed their drainage. By simply plugging the drainage outlets, the surface runoff would still drain as usual, but the wetlands would once again serve as on-site water storage areas. The secondary and tertiary benefits would include reducing phosphorus in surface runoff and enhancing wildlife habitat, respectively.

The proposed project sites are located throughout the northern Lake Okeechobee watershed in the following basins: S-65D and S-84, along the Lower Kissimmee River; S-154, and Taylor Creek/Nubbin Slough (S-191). Initially two pilot STAs and 10 small-scale restoration/ creation projects were planned. Those numbers are subject to change. An expanded effort for this critical project is being considered that would include all Lake Okeechobee subbasins in the northern part of the watershed that are contributing nutrients and other pollutants to the lake.

The first STA is located on Taylor Creek. It is a 193-acre site that was acquired from Grassy Island Ranch. The District, in conjunction with the USGS is conducting preconstruction monitoring that to determine the efficacy of the STA. This monitoring will continue after construction is complete. A second STA, approximately 1,000 acres in size, will be constructed adjacent to Nubbin Slough at the New Palm/Newcomer Dairy property acquired by the District through the Save Our Rivers Program. The USACE is designing and will construct both STAs.

For the small-scale sites, the SFWMD is designing and constructing modifications to improve stormwater retention, restore wetlands, and improve quality of discharge water. Components of the proposed modifications include plugging drainage ditches and installation of riser culverts in existing drainage ditches to retain water in currently overdrained historic wetlands. Some of the sites involve expansion of existing water storage ponds or creation of new impoundments. The sites will remain in private ownership and proposed project areas will require flowage easements with the landowners.

F3d. Isolated Wetland Restoration and Creation Program

Historically, isolated wetlands covered a significant percent of land area in the Lake Okeechobee watershed, capturing stormwater runoff and helping to retain phosphorus in the watershed. However, in the 1960s, many of these wetlands were drained to put more land into agricultural production, and in the process, have allowed more phosphorus to reach Lake Okeechobee. As a consequence, the elimination of wetlands has contributed to the accelerated eutrophication of Lake Okeechobee.

Restoration of ditched natural wetlands and the creation of new wetlands as filter marshes is one of the potential mechanisms for reducing phosphorus loading to Lake Okeechobee. One of the programs currently under way to restore and create new wetlands in the Lake Okeechobee watershed is the Lake Okeechobee Isolated Wetland Restoration and Creation Program.

The Lake Okeechobee Isolated Wetland Restoration and Creation Program is a voluntary landowner cost-sharing program that will be conducted from October 2000 to September 2003. This program offers landowners the opportunity to restore isolated wetlands that have previously been ditched, drained, and converted to agricultural uses. The SFWMD is administering the program with the cooperation of a multiagency team that includes the FDACs, the FDEP, the NRCS, the USFWS, and the IFAS. As of April 2002, eleven landowners had signed up for the program and design and construction had begun on two of the sites.

F3e. Phosphorus Source Control Grant Program

The goal of the Lake Okeechobee Phosphorus Source Control Grant Program is to identify, fund, and implement projects that reduce external phosphorus loads from the Lake Okeechobee watershed. The SFWMD is administering the program, but an interagency team that includes the FDEP, the FDAC, the NRCS, and the IFAS participated in the program coordination and selection of projects.

The program has two major components: 1) grant and 2) engineering oversight. The grant component is comprised of two separate funding releases and will be administered in four phases: 1) Project Selection 2) Implementation and Reporting, 3) Operation and Maintenance, and 4) Monitoring and Reporting. Under the engineering oversight component, the District will contract an engineering firm to verify that implementation of funded projects is performed in accordance with the funding agreement and grant application. The project selection phase has been completed for both funding releases.

F4. Lake Okeechobee Tributary Sediment Removal Demonstration Project

In 1997, the District sponsored a study to determine the relative magnitude of phosphorus content and transport potential of sediment from various tributaries in the northern portion of the Lake Okeechobee watershed that convey stormwater runoff to the lake and to analyze feasible management alternatives for source removal and control. That study, completed by Mock Roos and Associates (1997) concluded that sediment removal would reduce phosphorus loads to Lake Okeechobee. The total phosphorus reduction will be limited by a fraction of particulate phosphorus in the tributary bed load, which is about 25 percent. It was estimated between 5 to 25 percent of the particulate phosphorus entering the lake could be eliminated by direct sediment removal.

The Lake Okeechobee Tributary Sediment Removal Demonstration Project was developed in 1999 and is ongoing. It is a multiphase project. Project design and permitting has been completed and construction has begun. The project will be completed by October 1, 2003.

The project has been designed to demonstrate the phosphorus reduction benefits realized by tributary sediment removal. Before expanding sediment removal to other tributaries, this activity must be demonstrated to be technically feasible and economically viable. If the project demonstrates that either of the tested technologies can successfully trap sediments, the technology will be utilized in other tributaries by the District and/or private property owners. The specific objectives of the study are as follows:

- To determine if particulate phosphorus loading to Lake Okeechobee from the Lettuce Creek drainage basin may be reduced using either of two sediment removal technologies

- To demonstrate the feasibility of sediment removal in a tributary as a method to reduce phosphorus loading to the lake
- To perform a detailed assessment of effectiveness of these two technologies and their economic viability

The two sediment removal technologies that will be tested in this demonstration project are a continuous deflective separation (CDS) unit and a tributary sediment trap (TST). They were selected based on the following criteria:

- According to current literature, these technologies are effective in reducing particulate phosphorus loading.
- These technologies can be applied in open channel flow condition and have a high treatment capacity.
- These technologies are on the lower end of cost for treatment facilities.
- The treatment facilities can be easily maintained.

The CDS unit is a patented process for removal of bedding and suspended solids. It was developed in Australia by CDS Technologies, Ltd., and is manufactured in the United States by CDS Technologies, Inc. The CDS unit works by trapping pollutants using a separation screen. Stormwater runoff discharges into the center chamber of the CDS unit and then passes through a separation screen to an outer chamber prior to discharging downstream. Gross pollutants are trapped in a sump area located below the separation screen.

The use of a tributary sediment trap (TST) is recommended by the *Guidebook of Sediment Control Best Management Practices* (SFWMD, 1999a). The principle of sediment removal using a sediment trap is similar to a settling basin/water detention area. An artificial or natural water detention area in which water flow velocities are lowered, relative to inflows, to facilitate the settling of suspended solids. However, a trap contains a deepened section in addition to a widened section. Water velocities are suddenly slowed down by a porous barrier or baffle in a settling basin/trap, which allows sediment to settle into a collection area.

The project is being conducted at the site where Lettuce Creek discharges to the SFWMD conveyance system. Lettuce Creek is within the Nubbins Slough basin, which is located northeast of Lake Okeechobee. It discharges through the L-63S Canal and is one of the major sources of phosphorus load discharging into Lake Okeechobee. Lettuce Creek was selected for this sediment removal demonstration because it has the following characteristics:

- Continuous flow
- No upstream water control structures
- Relatively high sediment phosphorus content and particulate phosphorus concentrations
- Erosive soil

- Relatively high sediment transport rate
- Diversified land uses in the drainage basin
- High period of record and 12-month rolling average phosphorus concentration among the tributaries according to the data reported in the *Tributary Water Quality Monthly Report*.
- Both a CDS unit and a TST will be installed at the discharge site of Lettuce Creek. By installing both the CDS unit and the TST at one site, their performance on phosphorus removal can be compared.

The project will be conducted in three phases. Phase I includes the development of a work plan, land surveys, data collection and computation for engineering design, project engineering design, development of a quality assurance project plan, and project permitting. During Phase II, the CDS unit and the TST will both be constructed and installed, and monitoring instruments will be calibrated. In Phase III, the monitoring network implemented in Phase II will be operated and maintained for 12 months.

After 12 months of monitoring, the selected contractor will analyze monitoring data to determine whether either sediment removal technology should be applied to other tributaries. Data from the monitoring network will provide an understanding of phosphorus movement through the tributary system and sediment removal mechanisms. The total cost of construction, maintenance fees, and cost per unit phosphorus removal of each technology will be analyzed to determine if these technologies are technically and economically effective and which technology is the most cost-effective.

F5. Natural Resource Analysis of Lake Okeechobee Phosphorus Management Strategies

The Lake Okeechobee Protection Act (373.4595, F.S.) establishes extensive and comprehensive requirements for surface water improvements and management within Lake Okeechobee and its watershed. Cost-effectiveness in reducing phosphorus is an implicit part of the overall legislation, and it is explicitly referred to in various activities. This project will provide the framework and detailed information for comparing the cost-effectiveness of various phosphorus reduction treatments.

The purpose of this project is to provide an environmental (or natural resource) economic analysis of the alternative phosphorus management strategies that have been used, or are being considered, in the Lake Okeechobee watershed. Natural resources valuation principles will be utilized and will include the determination of the economic impacts to the surrounding communities that each of the strategies could present. Alternative phosphorus management strategies (beyond the Dairy Rule BMPs) are being examined to further reduce external nutrient loads to the lake in an effort to achieve the in-lake target phosphorus concentration of 40 ppb. Some of the phosphorus control strategies currently under consideration, or partially implemented, include implementation of the Dairy Rule, WOD regulation of nondairy land uses, confinement dairies, land acquisition with restrictions, reservoir-assisted STAs, implementation of BATs, implementation of enhanced BMPs, implementation of projects under the Phosphorus Source Control Grant Program, reclamation or creation of isolated wetlands to capture phosphorus and attenuate flows, use of residual and animal manure from outside the basin, removal of sediments in tributaries, and regional treatment systems.

Hazen and Sawyer Consultants (1995) determined the direct economic impacts to Okeechobee County and the region from the implementation of the Lake Okeechobee water quality programs that included the Dairy Rule, the Dairy Buy-Out Program, and the WOD Program. The Dairy Rule provides for the collection, storage, and land application of waste and nutrient-laden runoff HIAs surrounding and including the milking barns. However, the positive impacts from improved water quality conditions of Lake Okeechobee due to the water quality programs, such as increased sales, income, and employment related to Okeechobee's tourism industry, were not included in their economic impact evaluation. During the 1988 to 1993 study period analyzed by Hazen and Sawyer Consultants (1995), many of the dairies and landowners were constructing the production modifications needed to comply with the water quality programs, while other dairies were ceasing operation under the Dairy Buy-Out Program. Because the requirements under the water quality programs were not fully implemented until 1993, the full potential of the expected reductions in phosphorus loads into Lake Okeechobee did not take place until after the study period. This current project will continue where the efforts ended in the 1995 analysis, and will now include a full cost accounting of ten phosphorus control alternatives (PCAs) to further reduce the amount of phosphorus entering Lake Okeechobee.

The PCAs were chosen based on three criteria:

- Sufficient information is or will be available to allow for an adequate evaluation of benefits and costs associated with the PCA.
- The PCAs have the potential to successfully reduce phosphorus loading to Lake Okeechobee.
- The PCAs are being considered in planning programs.

Benefits and costs of each alternative to the District, to landowners, and to the regional economy will be described and quantified. The following PCAs were selected according to the above criteria:

1. Chemical treatment of runoff at the edge of property
2. Wetland treatment of runoff at the edge of property
3. Nonstructural management at the land parcel level
4. Optimization of Dairy Rule design or use of alternative waste management technologies
5. Enhanced cow-calf BMPs
6. Alternative land uses – convert dairy, citrus, field crop, and row crops to land uses such as wetlands, natural areas, cow-calf operations, and forage production

7. Reservoir-assisted STAs
8. System able to receive supplemental water from the lake
9. Tributary sediment removal
10. Terminal large-scale water treatment facilities

This study will identify benefits and costs of each PCA using a full cost accounting approach, which attempts to identify and quantify the social benefits and costs resulting from a policy decision. Decades of research into phosphorus reduction strategies in the Lake Okeechobee Basin and the EAA, and many current and new research and planning projects, will provide a wealth of data that may be used to provide an economic evaluation of alternatives.

The benefits and costs of the PCAs will be measured relative to baseline conditions that represent current management practices of landowners, to the extent that the available information will allow. This study will also consider the costs per unit of phosphorus reduction associated with a range of phosphorus input and output levels for those PCAs that can be effectively implemented at different scales.

A Computerized Alternatives Evaluation/Full Cost Accounting Model will be developed to allow for updating as new data and information become available. The benefit-cost analysis will be used in conjunction with a model that uses evaluation criteria to measure the relative benefits and costs of the alternative and will provide a ranking of alternatives based on the magnitude of itemized benefits and costs. This will allow the District to add and evaluate additional PCAs in the future.

K. CLASS I, III, AND IV STANDARDS

Historical (1988 to 2000) tributary inflow water quality data were evaluated to determine the level of compliance with numeric state water quality standards (Chapter 62-302.530, F.A.C.). Sample locations included 33 tributary stations located at all water control structures maintained by the SFWMD and the USACE; locations along the Kissimmee River, Taylor Creek/Nubbins Slough, Harney Pond and Indian Prairie canals, and Fisheating Creek; and all Everglades Protection District structures that drain into the lake through pump stations or culverts including the four Chapter 298 Districts and Closter Farms (**Figure 2-3**). In addition, in 1992, more than 60 previously unsampled water quality and biological parameters were collected during a 12-month monitoring program at the same 42 stations mentioned above (Ogburn et al., 1996).

The classification of tributary waters varies. For example, S308C and S77 waters must meet Class I (potable water supplies) criteria no matter if they are flowing into the lake or not. CULV10 and CULV10A waters flowing into the lake must meet Class I standards, but if water is not flowing into the lake, the water needs to meet only Class IV and Class III standards, respectively. Industrial Canal must meet Class III standards whether water is flowing into the lake or not. The observations were thus separated into inflow (**Table 2-4**) or no inflow (**Table 2-5**) to the lake, and then subdivided by the

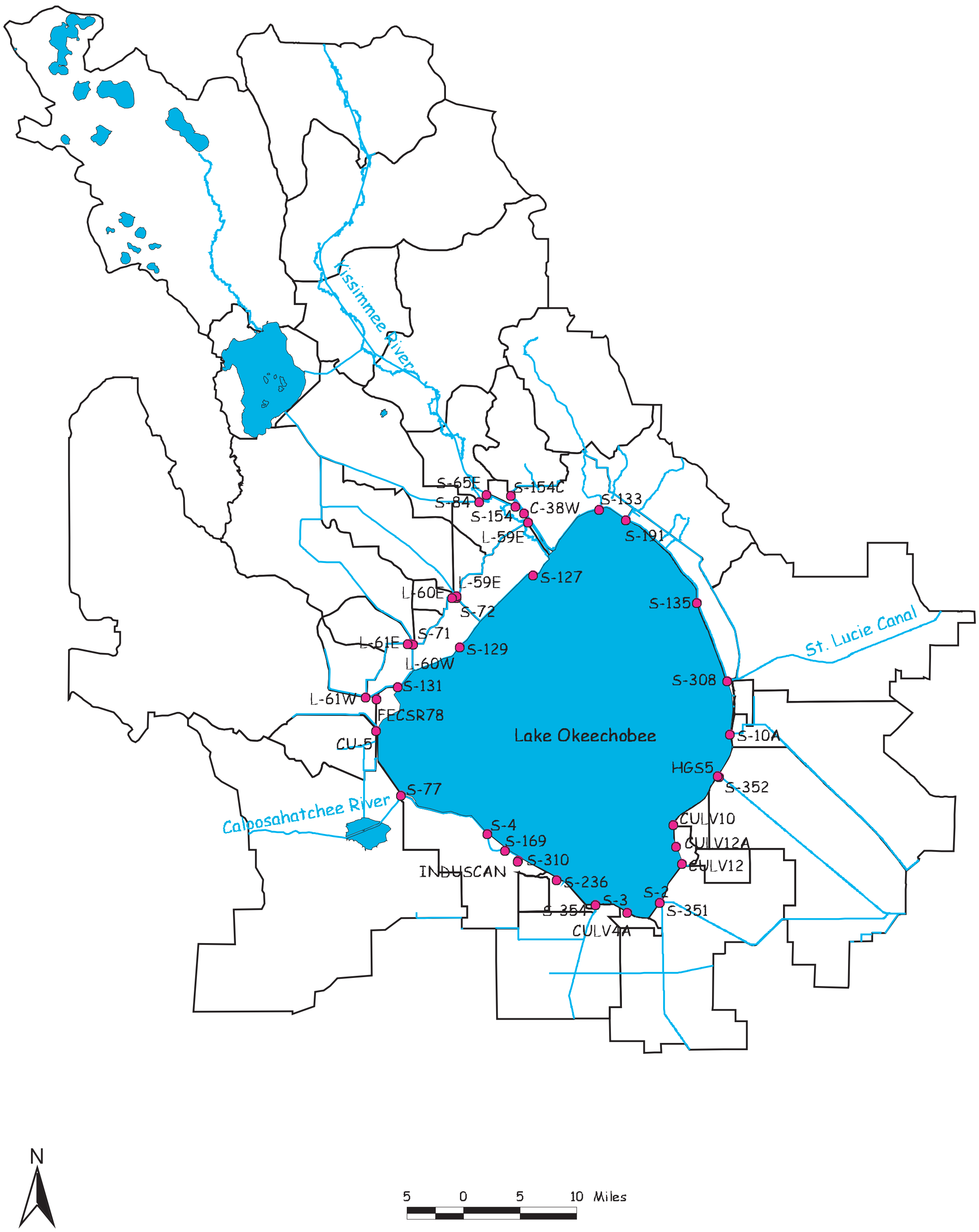

Figure 2-3. The tributary stations samples were collected from to determine compliance with Class I, III, and IV Standards

standards that each station must meet. Observations for each class parameter were summed to determine the overall percent noncompliance for each given parameter.

All values for each contaminant were summed and the percentage of instances that the criterion was exceeded was calculated for each class. An evaluation of these data from the 13-year period of 1988 to 2000 indicated that major inflows generally comply with applicable state water quality criteria with the exception of dissolved oxygen, iron, and conductivity (**Table 2-4**). Water quality criteria for most monitored parameters were exceeded in less than 25 percent of the measurements at specific locations. The criteria for arsenic, trace metals (cadmium, copper, lead, mercury, and zinc) and organic contaminants were rarely exceeded in the lake inflows. For most tributaries, fewer than 20 trace metal samples were taken over the 13-year period while waters were flowing into the lake. Due to this small sample size, the percentage of instances that criterion was exceeded was not calculated for these contaminants. Based on the number of times the criteria were exceeded, water quality associated with inflows has not substantively impaired the designated uses of the lake. However, additional monitoring of biological conditions and trace metals during inflow conditions may be warranted to document whether the inflows meet their designated use.

Parameters that widely or frequently exceeded the criteria included alkalinity, chloride, dissolved oxygen, conductivity, and iron. Pesticide criteria were infrequently exceeded during the quarterly sampling in the supplemental monitoring program (Ogburn et al., 1996), but pesticides and other organics are included in this evaluation despite the very limited database, and because of their potential for ecological impacts.

K1. pH

The Class I, III, and IV criteria for pH include minimum (6.0) and maximum (8.5) values, unless natural background conditions are documented to be lower or higher. The criteria were developed primarily to protect aquatic life. More than 10 percent of the samples at the Fisheating Creek station (FECSR78) exceeded the criteria during periods of inflow (**Table 2-4**). These samples had many low pH values, which appeared to be associated with naturally occurring humic and fulvic acids from wetlands in the Fisheating Creek drainage basin.

K2. Alkalinity

The criteria for alkalinity require a minimum value of 20 ppm as calcium carbonate ($CaCO_3$) for Class I and III waters, while no minimum and a maximum of 600 ppm is required for Class IV waters. Alkalinity buffers pH changes, and the bicarbonate and carbonate that contribute to alkalinity can complex some trace metals and reduce their potential toxicity to aquatic organisms. Low alkalinity can inhibit shell formation by aquatic snails and other mollusks.

Table 2-4. The percentage of instances that Class I and III criteria was exceeded for tributary samples taken during inflow periods to Lake Okeechobee[a]

STATION	pH	Alkalinity	Conductivity	Chloride	Dissolved Oxygen	Total Dissolved Solids	Turbidity	Un-ionized Ammonia	Nitrate	Iron	Arsenic	Cadmium	Copper	Lead	Zinc	Mercury
Class I																
CULV10	0.0	2.0	74.5	52.1	84.8	ND	22.9	33.3	2.2	ND	ND	ND	ND	ND	ND	ND
	45	49	47	48	46	7	48	48	45	12	12	11	11	11	11	11
CULV10A	3.5	2.2	19.5	11.1	89.4	ND	3.4	7.0	0.0	65.4	0.0	0.0	0.0	0.0	0.0	0.0
	86	90	87	90	85	17	89	86	87	26	26	24	23	24	24	23
CULV12	0.0	2.8	34.3	11.1	82.4	ND	5.6	13.9	5.6	ND	ND	ND	ND	ND	ND	ND
	34	36	35	36	34	7	36	36	36	10	10	9	9	9	9	10
CULV12A	1.0	0.0	86.1	80.6	86.9	ND	1.9	16.3	0.0	19.2	0.0	4.0	0.0	0.0	0.0	0.0
	101	103	101	103	99	17	104	104	97	26	26	25	25	25	25	25
CULV4A	0.0	1.6	71.2	9.7	96.6	ND	1.7	13.6	1.9	ND	ND	ND	ND	ND	ND	ND
	59	61	59	62	59	6	60	59	54	9	9	8	8	8	8	10
CULV5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	12	14	13	14	12	2	14	14	14	4	4	4	4	4	4	4
FECSR78	15.8	72.1	23.4	0.0	55.2	0.0	0.0	1.1	0.0	91.1	0.0	7.1	0.0	11.9	2.4	0.0
	183	190	184	189	181	27	186	189	172	45	44	42	42	42	42	41
HGS5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2	3	2	3	2	1	3	3	3	1	1	1	1	1	1	1
S127	0.0	0.0	11.9	14.9	65.7	ND	0.0	1.5	0.0	ND	ND	ND	ND	ND	ND	ND
	67	68	67	67	67	10	67	67	63	15	15	13	13	13	13	15
S129	0.0	0.0	0.0	0.0	50.0	ND	0.0	1.9	0.0	ND	ND	ND	ND	ND	ND	ND
	50	53	50	53	48	7	53	52	45	11	11	10	10	10	10	11
S131	1.9	0.0	0.0	0.0	51.9	ND	0.0	1.9	0.0	ND	ND	ND	ND	ND	ND	ND
	53	55	54	55	52	8	55	53	44	11	11	11	11	11	11	11
S133	0.0	0.0	2.3	0.0	65.9	ND	0.0	0.0	0.0	ND	ND	ND	ND	ND	ND	ND
	44	45	44	45	44	7	44	45	45	11	12	12	12	12	12	11

a. The upper number in each cell indicates the number of samples collected, while the lower number represents the percentage the criterion was exceeded. The key below explains the color coding

- 25% or more of samples exceed criterion
- Between 10% and 25% of samples exceed criterion
- Less than 10% of samples exceed criterion
- ND Not determined
- Criterion has not been established

Table 2-4. The percentage of instances that Class I and III criteria was exceeded for tributary samples taken during inflow periods to Lake Okeechobee[a] (continued)

STATION	pH	Alkalinity	Conductivity	Chloride	Dissolved Oxygen	Total Dissolved Solids	Turbidity	Un-ionized Ammonia	Nitrate	Iron	Arsenic	Cadmium	Copper	Lead	Zinc	Mercury
S135	0.0	2.3	0.0	0.0	38.1	ND	0.0	2.3	0.0	ND	ND	ND	ND	ND	ND	ND
	42	43	42	43	42	7	43	43	38	8	8	8	8	8	8	8
S191	2.6	3.4	19.4	1.9	68.5	ND	0.9	4.7	0.0	86.2	0.0	0.0	3.7	0.0	3.6	0.0
	386	178	377	376	371	17	212	403	397	29	29	28	27	28	28	28
S2	0.0	2.3	31.6	0.0	98.2	ND	15.2	15.2	0.0	ND	ND	ND	ND	ND	ND	ND
	57	43	57	48	56	7	46	66	52	9	9	9	9	9	9	7
S236	0.0	0.0	79.2	68.0	87.5	ND	3.8	11.5	0.0	ND	ND	ND	ND	ND	ND	ND
	24	26	24	25	24	5	26	26	25	7	7	7	7	7	7	7
S3	0.0	0.0	17.1	10.3	100.0	ND	0.0	18.0	0.0	ND	ND	ND	ND	ND	ND	ND
	41	24	41	29	41	7	30	50	37	8	8	8	8	8	8	8
S308C	0.0	0.0	2.7	0.0	41.7	ND	8.6	2.8	0.0	ND	ND	ND	ND	ND	ND	ND
	36	36	37	36	36	5	35	36	34	9	9	9	9	9	9	9
S4	0.0	4.0	0.0	0.0	70.8	ND	0.0	0.0	0.0	ND	ND	ND	ND	ND	ND	ND
	24	25	24	25	24	1	24	24	23	4	4	4	4	4	4	4
S77	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2	2	2	2	2	0	2	2	2	0	0	0	0	0	0	0
Class I Total	3.3	13.2	27.0	12.3	71.2	44.8	2.7	7.4	0.3	52.9	0.0	1.6	0.4	2.1	0.8	0.0
	1,348	1,144	1,347	1,349	1,325	165	1,177	1,406	1,313	255	255	243	241	243	243	244
Class III																
C38W	4.9	0.0	97.5		43.4		7.8	2.3		0.0	0.0	11.9	0.0	0.0	0.0	0.0
	123	130	119		122		129	128		44	44	42	41	42	42	39
INDUSCAN	0.0	0.0	19.0		55.2		5.5	3.5		ND	ND	ND	ND	ND	ND	ND
	58	57	58		58		55	57		12	12	10	10	10	10	12
L59E	0.0	9.1	54.5		100.0		0.0	9.5		ND	ND	ND	ND	ND	ND	ND
	20	22	22		20		21	21		3	3	3	3	3	3	3

a. The upper number in each cell indicates the number of samples collected, while the lower number represents the percentage the criterion was exceeded. The key below explains the color coding

- 25% or more of samples exceed criterion
- Between 10% and 25% of samples exceed criterion
- Less than 10% of samples exceed criterion
- ND Not determined
- Criterion has not been established

Table 2-4. The percentage of instances that Class I and III criteria was exceeded for tributary samples taken during inflow periods to Lake Okeechobee[a] (continued)

STATION	pH	Alkalinity	Conductivity	Chloride	Dissolved Oxygen	Total Dissolved Solids	Turbidity	Un-ionized Ammonia	Nitrate	Iron	Arsenic	Cadmium	Copper	Lead	Zinc	Mercury
L59W	4.5	2.6	8.1		65.8		0.0	2.7		0.0	0.0	6.9	0.0	0.0	0.0	0.0
	111	115	111		111		113	111		31	31	29	28	29	29	31
L60E	5.0	4.8	8.0		56.6		0.0	1.0		3.6	0.0	3.7	0.0	0.0	0.0	0.0
	101	104	100		99		103	101		28	28	27	26	27	27	25
L60W	3.4	0.0	5.2		64.9		0.0	1.7		ND	ND	ND	ND	ND	ND	ND
	58	60	58		57		59	58		16	16	13	13	14	13	13
L61E	ND	ND	ND		ND		ND	ND		ND	ND	ND	ND	ND	ND	ND
	16	16	16		16		16	16		7	6	6	6	6	6	6
L61W	4.7	1.5	18.8		82.8		0.0	1.6		14.3	0.0	ND	ND	ND	ND	ND
	64	65	64		64		63	63		21	21	19	19	19	19	19
S154	2.8	5.2	21.4		69.4		0.0	5.1		ND	ND	ND	ND	ND	ND	ND
	181	96	173		173		109	196		15	15	14	14	14	14	14
S154C	1.7	0.0	96.7		77.3		0.0	2.2		2.8	0.0	2.9	0.0	0.0	0.0	0.0
	180	188	182		181		188	183		36	35	34	34	34	34	33
S65E	5.2	10.7	1.5		39.4		0.0	3.4		1.4	0.0	3.6	1.8	5.5	0.0	0.0
	542	366	521		520		431	590		281	59	55	55	55	55	56
S71	4.6	14.5	9.0		69.5		0.0	4.9		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	174	186	177		174		184	182		34	34	32	32	32	32	29
S72	0.0	4.9	13.8		82.3		0.0	2.5		ND	ND	ND	ND	ND	ND	ND
	80	82	80		79		79	80		19	19	18	18	18	18	18
S84	4.1	36.2	12.2		26.7		0.0	3.1		0.0	0.0	14.8	3.7	14.8	0.0	0.0
	271	138	270		270		135	293		29	29	27	27	27	27	27
Class III Total	3.9	8.4	23.2		54.1		0.8	3.2		3.8	0.0	4.9	0.6	2.7	0.3	0.0
	1,979	1,625	1,951		1,944		1,685	2,079		576	352	329	326	330	329	325

a. The upper number in each cell indicates the number of samples collected, while the lower number represents the percentage the criterion was exceeded. The key below explains the color coding

(orange)	25% or more of samples exceed criterion
(yellow)	Between 10% and 25% of samples exceed criterion
(green)	Less than 10% of samples exceed criterion
ND	Not determined
(grey)	Criterion has not been established

Table 2-5. The percentage of instances that the Class I, III, and IV criteria was exceeded for tributary samples taken during periods of no inflow to Lake Okeechobee[b]

STATION	pH	Alkalinity	Conductivity	Chloride	Dissolved Oxygen	Total Dissolved Solids	Turbidity	Un-ionized Ammonia	Nitrate	Iron	Arsenic	Cadmium	Copper	Lead	Zinc	Mercury
Class I																
S308C	3.8	0.6	2.5	0.0	12.0	0.0	17.0	0.0	0.0	87.9	0.0	0.0	0.0	9.7	0.0	0.0
	158	159	159	158	158	24	159	153	147	33	33	31	30	31	31	31
S77	2.5	3.0	3.0	0.0	44.7	0.0	1.0	2.6	0.0	15.2	0.0	0.0	0.0	0.0	2.2	0.0
	200	198	200	200	197	28	200	196	195	46	47	45	45	45	45	44
Total Class I	3.1	2.0	2.8	0.0	30.1	0.0	8.1	1.4	0.0	45.6	0.0	0.0	0.0	3.9	1.3	0.0
	358	357	359	358	355	52	359	349	342	79	80	76	75	76	76	75
Class III																
C38W	ND	ND	ND		ND		ND	ND		ND	ND	ND	ND	ND	ND	ND
	13	13	10		12		13	13		1	1	1	1	1	1	1
CULV10A	1.9	0.0	5.8		25.0		13.5	1.1		38.1	0.0	5.0	0.0	5.0	0.0	ND
	104	96	103		104		96	90		21	20	20	20	20	20	17
CULV5	6.5	2.4	19.4		87.0		2.4	0.8		9.8	0.0	5.3	0.0	2.6	0.0	0.0
	124	126	124		123		125	125		41	40	38	38	38	38	37
FECSR78	ND	ND	ND		ND		ND	ND		ND	ND	ND	ND	ND	ND	ND
	7	7	7		7		7	7		4	4	4	4	4	4	4
HGS5	2.7	0.5	15.4		28.2		22.3	7.6		28.6	0.0	0.0	0.0	0.0	0.0	0.0
	294	221	293		291		220	223		49	48	46	46	46	46	48
INDUSCAN	1.9	0.9	21.0		38.8		0.0	4.6		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	104	106	105		103		109	109		31	30	30	30	30	30	29
L59E	4.0	0.9	45.6		72.5		1.9	7.4		7.7	0.0	8.1	2.8	0.0	2.7	0.0
	101	109	103		102		108	108		39	39	37	36	37	37	35
L59W	0.0	1.9	12.5		46.8		0.0	5.7		ND	ND	ND	ND	ND	ND	ND
	48	53	48		47		52	53		14	14	14	14	14	14	14
L60E	3.6	1.7	8.8		48.2		0.0	0.0		ND	ND	ND	ND	ND	ND	ND
	55	60	57		56		60	59		19	19	18	18	18	18	18

b. The upper number in each cell indicates the number of samples collected, while the lower number represents the percentage the criterion was exceeded. The key below explains the color coding

- 25% or more of samples exceed criterion
- Between 10% and 25% of samples exceed criterion
- Less than 10% of samples exceed criterion
- ND Not determined
- No criterion has been established

Table 2-5. The percentage of instances that the Class I, III, and IV criteria was exceeded for tributary samples taken during periods of no inflow to Lake Okeechobee[b] (continued)

STATION	pH	Alkalinity	Conductivity	Chloride	Dissolved Oxygen	Total Dissolved Solids	Turbidity	Un-ionized Ammonia	Nitrate	Iron	Arsenic	Cadmium	Copper	Lead	Zinc	Mercury
L60W	8.6	7.0	5.3		59.6		0.0	6.0		3.6	0.0	0.0	0.0	3.6	3.6	0.0
	93	100	95		94		99	100		28	28	28	28	28	28	25
L61E	2.5	4.7	9.8		50.0		0.8	1.6		0.0	0.0	3.0	0.0	3.0	0.0	0.0
	122	128	123		122		126	127		35	35	33	33	33	33	31
L61W	1.5	1.5	4.5		60.6		1.5	1.5		ND	ND	ND	ND	ND	ND	ND
	65	67	66		66		67	67		19	18	18	18	18	18	17
S127	3.3	0.8	17.9		38.5		0.8	2.4		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	122	127	123		122		127	127		34	33	33	32	33	33	29
S129	0.0	0.0	2.6		23.5		0.0	1.7		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	115	120	116		115		120	121		35	35	34	34	34	34	31
S131	4.0	0.0	0.0		28.8		0.0	0.8		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	125	128	125		125		126	128		39	38	36	36	36	36	34
S133	0.0	0.8	1.6		51.3		0.0	0.0		0.0	0.0	0.0	0.0	0.0	3.0	0.0
	121	127	122		119		126	124		36	35	33	32	33	33	32
S135	3.2	1.5	0.0		30.6		0.8	0.8		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	124	132	126		124		131	130		40	40	38	37	38	38	37
S154	2.2	1.5	22.6		45.3		0.9	3.4		81.3	0.0	6.5	0.0	0.0	0.0	0.0
	365	200	350		349		226	387		32	31	31	31	31	31	28
S154C	0.0	0.0	89.5		92.1		0.0	2.4		ND	ND	ND	ND	ND	ND	ND
	38	41	38		38		41	41		12	12	11	10	11	11	12
S191	3.3	0.7	24.0		32.4		1.6	3.3		0.0	0.0	0.0	0.0	0.0	5.0	0.0
	304	148	296		296		183	337		23	21	20	20	20	20	21
S2	0.6	0.0	31.4		37.1		3.6	8.4		2.4	0.0	0.0	0.0	0.0	0.0	0.0
	171	171	172		170		168	166		42	44	42	42	42	42	41
S3	2.8	1.1	30.6		28.2		1.7	4.6		2.3	0.0	2.4	0.0	0.0	0.0	0.0
	180	179	180		177		178	175		44	44	42	42	42	42	42

b. The upper number in each cell indicates the number of samples collected, while the lower number represents the percentage the criterion was exceeded. The key below explains the color coding

25% or more of samples exceed criterion

Between 10% and 25% of samples exceed criterion

Less than 10% of samples exceed criterion

ND Not determined

No criterion has been established

Table 2-5. The percentage of instances that the Class I, III, and IV criteria was exceeded for tributary samples taken during periods of no inflow to Lake Okeechobee[b] (continued)

STATION	pH	Alkalinity	Conductivity	Chloride	Dissolved Oxygen	Total Dissolved Solids	Turbidity	Un-ionized Ammonia	Nitrate	Iron	Arsenic	Cadmium	Copper	Lead	Zinc	Mercury
S4	1.5	0.0	12.5		25.4		0.0	5.7		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	136	143	136		134		143	141		46	45	43	43	43	43	41
S65E	1.6	1.9	0.0		18.2		0.0	1.3		0.0	ND	ND	ND	ND	ND	ND
	62	52	56		55		66	75		35	4	3	3	3	3	3
S71	5.3	4.1	7.4		45.7		1.0	1.0		ND	ND	ND	ND	ND	ND	ND
	94	98	94		94		98	96		15	14	14	14	14	14	14
S72	3.1	4.0	9.3		43.8		0.0	1.0		0.0	0.0	3.4	0.0	3.4	0.0	0.0
	96	101	97		96		101	100		30	30	29	28	29	29	28
S84	2.0	18.8	11.1		13.2		0.0	2.9		ND	ND	ND	ND	ND	ND	ND
	198	101	199		197		100	208		19	19	19	18	19	19	14
Total Class III	2.8	2.0	16.6		39.2		3.0	3.4		7.9	0.0	1.8	0.3	1.0	0.7	0.1
	3,381	2,954	3,364		3,338		3,016	3,437		783	741	715	708	715	715	683
Class IV																
CULV10	1.7	0.0	37.8		34.2		1.6			0.0	0.0		0.0	0.0	0.0	0.0
	120	124	119		117		125			37	36		36	36	36	36
CULV12	4.0	0.0	27.2		20.3		0.8			0.0	0.0		0.0	0.0	0.0	0.0
	126	134	125		123		132			39	38		38	38	38	37
CULV12A	1.4	0.0	45.1		55.7		1.4			0.0	0.0		0.0	0.0	0.0	ND
	71	74	71		70		73			21	20		20	20	20	19
CULV4A	0.0	0.0	23.2		29.7		2.7			0.0	0.0		0.0	0.0	0.0	0.0
	112	114	112		111		113			36	35		35	35	35	34
S236	0.8	0.0	61.1		33.6		0.0			0.0	0.0		0.0	0.0	0.0	0.0
	126	131	126		125		131			39	38		38	38	38	34
Total Class IV	1.6	0.0	38.7		32.8		1.2			0.0	0.0		0.0	0.0	0.0	0.0
	555	577	553		546		574			172	167		167	167	167	160

b. The upper number in each cell indicates the number of samples collected, while the lower number represents the percentage the criterion was exceeded. The key below explains the color coding

(orange)	25% or more of samples exceed criterion
(yellow)	Between 10% and 25% of samples exceed criterion
(green)	Less than 10% of samples exceed criterion
ND	Not determined
(gray)	No criterion has been established

During inflow conditions, low alkalinity criteria were exceeded in more than 25 percent of samples at FECSR78 (Fisheating Creek) and S84, and were exceeded in more than 10 percent of the samples at S65E and S71 (**Table 2-4**). Low alkalinity values were directly associated with low pH. Low alkalinity appears to be a natural condition in the inflow systems where it was documented. Since alkalinity within the lake very rarely was below the minimum value and no samples exceeded the maximum value, the instances of low alkalinity in these tributaries has not contributed to any degradation of the lake.

K3. Chloride

The Class I chloride criterion (250 ppm) is based on drinking water concerns, as high levels of chloride can give drinking water a salty taste. Class III and IV criteria have not been established for chloride. The chloride criterion was not exceeded during no inflow condition (**Table 2-5**), but was exceeded during inflow conditions more than 25 percent of the time at three stations (CULV10, CULV12A, and S236), and exceeded more than 10 percent of the time at four other stations (CULV10A, CULV12, S127, and S3) (**Table 2-4**).

Five of the stations with chloride criterion violations are located along the southeastern shore of the lake (**Figure 2-3**). Shallow ground water along the southeastern shore of the lake is affected by chloride and other salts that remain from the Pleistocene Era, when much of Florida was covered by shallow seas (Schroeder et al., 1954). Therefore, the inflows with high chloride concentrations appear to be related to ground water seepage into the canals, and they do not appear to impact the use of the lake as a source of drinking water.

K4. Dissolved Oxygen

Adequate levels of dissolved oxygen are necessary for aquatic animals to respire. The Class I and III criteria require a minimum of 5.0 ppm, and the Class IV minimum is 3.0 ppm during inflow conditions. The Class I and III criteria for dissolved oxygen were exceeded in more than 25 percent of the samples in all of the stations with 20 or more samples (**Table 2-4**). During no inflow conditions, the criteria were exceeded 25 percent of the time at all but 5 stations with 20 or more samples. At these 5 stations, the criteria were exceeded 10 percent of the time.

Many of the inflow stations showed a greater tendency for the dissolved oxygen criteria to be exceeded when water was flowing toward the lake, as opposed to when water was not flowing towards the lake, especially for stations at the southern end of the lake (**Figure 2-3** and **Tables 2-4** and **2-5**). This may be due to seepage of ground water with low dissolved oxygen concentrations into canals during pumping events. Canal water levels can be drawn down faster than ground water levels by pumping at control structures causing ground water to seep into the canals. Ground water typically has low dissolved oxygen levels that tend to reduce the dissolved oxygen levels in the canals. However, no studies have been conducted to document whether seepage into canals has a significant impact on surface water dissolved oxygen concentrations during pump events.

Dissolved oxygen fluctuates naturally in water bodies because of many physical and biological factors. The data collected on dissolved oxygen is done on a snapshot basis, and the time of sampling can have an impact on the values. Dissolved oxygen values during extended periods of no inflow at a structure can also play a role. Chronically low dissolved oxygen values can be the result of anthropogenic influences, but they can also be a natural characteristic of wetlands and other low energy systems. Schwartz (1985) concluded that the low dissolved oxygen values in Taylor Creek/Nubbins Slough, Fisheating Creek, and the Kissimmee River systems were due to drainage from extensive wetlands systems in their basins. Loading of oxygen-demanding substances and ground water seepage into the drainage systems around the lake also may contribute to the low dissolved oxygen values documented in the inflows. In-lake criteria were exceeded less than two percent of the time at all locations (**Table 3-4** in **Chapter 3**), thus they are of no great concern. However, additional monitoring may be needed to determine the significance of the potential causes of low dissolved oxygen before management strategies are evaluated.

K5. Total Dissolved Solids

The Class I criterion for total dissolved solids is no greater than 500 ppm on a monthly averaged basis or not greater than 1,000 ppb at any time. No Class III or IV criteria for total dissolved solids have been established. During periods of no inflow, the Class I criterion for total dissolved solids was not exceeded (**Table 2-5**). During periods of inflow to the lake, less than 20 samples were taken for each tributary, with the exception of FECSR78, so the percentage of instances that the criterion was exceeded could not be calculated. However, a summation of all of the observations show that the Class I criterion was exceeded over 45 percent of the time (**Table 2-4**). Based on this finding it is recommended that the tributaries be sampled on a regular basis for total dissolved solids.

K6. Turbidity

Turbidity is evaluated with respect to background values. The criterion allows a maximum of 29 nephelometric turbidity units (NTUs) above background. Background turbidity for each station was assumed to be the median (i.e., 50 percent of the samples are less than and 50 percent of the samples are greater than the median value). More than 10 percent of the samples taken at two stations during inflow conditions (CULV10 and S2) and three other stations during no inflow conditions (S308C, CULV10A, and HGS5) exceeded the criterion (**Tables 2-4** and **2-5**). Watershed management strategies may reduce sediment loading and turbidity levels in canals.

K7. Un-ionized Ammonia

Aqueous ammonia can be present as un-ionized ammonia and as ammonium ion. Un-ionized ammonia is the form that is toxic to some aquatic organisms. The criterion allows up to 0.02 ppm un-ionized ammonia to be present in the water. The proportion of un-ionized ammonia increases with increasing pH and temperature. The un-ionized ammonia criteria was exceeded at many tributary stations, but these instances were generally infrequent. During no inflow conditions no station had more than 10 percent of samples exceeding the criterion (**Table 2-5**). During inflow conditions one station (CULV10) exceeded the criterion in more than 25 percent of the samples and six stations (CULV12, CULV12A, CULV4A, S2, S236, and S3) exceeded the criterion in more than 10 percent of the samples (**Table 2-4**). These high levels are most likely related to anthropogenic sources of nitrogen, such as land spreading of sludge and/or agricultural fertilizers.

K8. Iron

The Class I, III, and IV standards for iron are 0.3, 1.0, and 1.0 ppm, respectively, During inflow periods, only 4 stations that are required to meet Class I standards for iron (CULV10A, CULV12A, FECSR78, and S191) had been sampled 20 or more times (**Table 2-4**). CULV12A exceeded the criterion more than 10 percent of the time while the three others exceeded Class I criterion more than 25 percent of the time. Only one station required to meet Class III standards during inflow periods, L61W, exceeded this standard more than 10 percent if the time (**Table 2-4**).

During no inflow periods, both stations (S308C and S77) that are required to meet Class I standards exceeded the criterion for iron. S308C exceeded the Class I standard more than 25 percent of the time and S77 more than ten percent of the time (**Table 2-5**). Class III standards were exceeded more than 25 percent of the time at three stations: CULV10A, HGS5, and S154.

K9. Arsenic and Trace Metals (Cadmium, Copper, Lead, Zinc, and Mercury

The Class I criterion for arsenic is 50 ppb. The Class I criteria for cadmium, copper, lead, and zinc are calculated as a function of water hardness, and, therefore, do not have specific values. The historical database generally had less than 40 observations each for arsenic, cadmium, copper, lead, mercury, and zinc for each tributary for both periods of inflow or no inflow to the lake (**Tables 2-4** and **2-5**). Because of the small sample size (less than 20), the percentage that the criteria were exceeded were not determined at a number of tributaries. However, when data for each metal was summed for each class, the number of samples exceeding the criteria for periods of inflow was less than 10 percent for both Class I and Class III criteria (**Table 2-4**). The criteria for arsenic were not exceeded in either class.

Most likely, the trace metal criteria is being exceeded due to anthropogenic activities and sources such as agricultural uses of sludge, fertilizers, and pesticides; burning of fossil fuels and wastes; and gasoline additives. The limited amount of trace metal data makes it difficult to determine if management strategies need to be implemented to reduce trace metal concentrations. The District's monthly monitoring program should be modified to include trace metals to facilitate a more conclusive assessment of the potential need for management measures to control trace metals within the tributaries.

K10. Organics and Pesticides

Pesticides and herbicides could be found in inflow samples because of the dominance of agricultural land uses in much of the Lake Okeechobee basin. During 1993 and 1994, CULV10 was the only location with detectable levels of pesticides (Ogburn et al., 1996). During two quarterly sampling events, concentrations of dieldrin and dichlor diphenyl trichlor (DDT) exceeded criteria in samples taken at CULV10. One instance of the toxaphene criteria being exceeded was documented at CULV10. At CULV10A, the polycyclic aromatic hydrocarbon criterion (2-methyl naphthalene) was exceeded once.

The results indicated that pesticides and other organic contaminants do not chronically exceed the criteria. These results are also supported by the sediment sampling analysis that showed only dichlor diphenyl dichlor (DDD-p,p') and dichlor diphenyl ethylene (DDE-p,p') were above the detection limit in seven and nine of the 31 samples taken, respectively. For the tributaries, these parameters were only sampled four times at each station, and the seasonal application of pesticides and variations in transport to surface waters based on rainfall patterns could have affected the likelihood of detecting organic contaminants. Therefore, additional organic monitoring may be needed in conjunction with the District's existing monitoring program to allow conclusions to be made regarding the instances of the criteria being exceeded for pesticides, herbicides, and other organic contaminants. The list of organic parameters from the supplemental monitoring program should be reduced to focus on compounds that are known to have potential sources in the watershed, such as pesticides, herbicides, and petroleum hydrocarbons. Quarterly sampling for organics was recommended, and the schedule within each quarter should be based on seasonal uses of agricultural chemicals and/or periods of inflow to the lake.

K11. Coliforms

Ogburn et al. (1996) also measured total and fecal coliforms at the tributaries throughout a year and found instances of criteria for both being exceeded (**Table 2-6**). Of the 87 fecal coliform measurements taken during inflow conditions, 22 were above the criteria. However, only 9 of the 84 measurements of total coliforms were above the criteria during inflow conditions. It is recommended that a routine monitoring for fecal and total coliforms be initiated in the District's monitoring program.

K12. Recommended Class I and III Management Strategies for Tributaries

Based on existing land uses and water quality conditions in the Lake Okeechobee basin, several strategies for canals and marinas may be applicable to the lake inflows:

- **Canals** - Oxygen injection, air injection, sediment removal, and constructed wetlands
- **Marinas** - Liquid waste management and boat maintenance control measures

Table 2-6. Results of fecal and total coliform measurements taken in lake okeechobee tributaries and in-lake stations from October 1993 to September 1994[cd]

	Fecal Coliforms								Total Coliforms			
	Inflow				No Inflow				Inflow		No Inflow	
	Class I		Class III		Class I		Class III		Class I and III		Class I and III	
Station	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples
CULV10	2	2	.	.	.	.	.	.	1	2	.	.
CULV10A	0	4	.	.	.	.	1	5	0	4	3	5
CULV12	1	2	.	.	.	.	.	.	0	2	.	.
CULV12A	4	4	.	.	.	.	.	.	3	4	.	.
CULV4A	2	2	.	.	.	.	.	.	1	2	.	.
CULV5	.	0	.	.	.	.	1	12	.	0	0	12
FECSR78	1	6	.	.	.	.	1	6	0	6	1	6
HGS5	1	3					2	6	0	3	2	6
INDUSCAN	.	.	3	4	.	.	0	8	0	4	2	8
L001			.	.	0	12	.	.			1	12
L002			.	.	0	12	.	.			1	12
L003			.	.	0	12	.	.			0	12
L004			.	.	0	12	.	.			1	12
L005			.	.	0	12	.	.			0	12
L006			.	.	0	12	.	.			0	12
L007			.	.	0	12	.	.			0	12
L59E	.	.	0	1	.	.	3	11	0	1	2	11
L59W	.	.	0	11	.	.	0	1	1	10	0	1
L60E	.	.	1	6	.	.	0	6	1	5	0	6
L60W	.	.	1	10	.	.	0	2	1	9	0	2
L61E	.	.	.	0	.	.	0	12	.	0	2	11
L61W	.	.	.	0	.	.	3	12	.	0	0	12
LZ2			.	.	0	12	.	.			1	12
LZ30			.	.	0	12	.	.			1	12
S127	0	1	.	.	.	.	0	11	0	1	1	11
S129	1	2	.	.	.	.	0	10	0	2	1	9
S131	1	1	.	.	.	.	1	11	0	1	0	11
S133	0	1	.	.	.	.	0	11	0	1	0	11
S135	0	2	.	.	.	.	0	8	0	2	1	8
S154	.	.	.	0	.	.	1	12	.	0	0	12
S154C	.	.	1	12	.	.	.	0	1	12	.	0
S191	1	1	.	.	.	.	0	11	0	1	0	11
S2	0	1	.	.	.	.	1	11	0	1	1	11

c. Source = Ogburn et al., 1996

d. The key to the shading is as follows:

In-lake samples Class I no inflow criterion only

Standard does not apply for this station and category

Table 2-6. Results of fecal and total coliform measurements taken in lake okeechobee tributaries and in-lake stations from October 1993 to September 1994[cd] (continued)

	Fecal Coliforms								Total Coliforms			
	Inflow				No Inflow				Inflow		No Inflow	
	Class I		Class III		Class I		Class III		Class I and III		Class I and III	
Station	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples	Number of Times Criterion Exceeded	Number of Samples
S236	1	1	.	.	.	.	.	.	0	1	.	.
S3	.	0	.	.	.	.	0	12	.	.	1	12
S308C	1	5	.	.	0	6	.	.	0	5	0	6
S4	.	0	.	.	.	.	1	12	.	.	1	12
S65E	.	.	0	1	.	.	0	11	0	1	0	11
S71	.	.	0	1	.	.	0	11	0	1	0	10
S72	.	.	0	2	.	.	2	10	0	2	1	9
S77	.	0	.	.	0	8	.	.	.	0	0	8
S84	.	.	0	1	.	.	0	11	0	1	0	11
TOTAL	16	38	6	49	0	122	17	233	9	84	24	351

c. Source = Ogburn et al., 1996

d. The key to the shading is as follows:

In-lake samples Class I no inflow criterion only

Standard does not apply for this station and category

- **Administrative** - Mixing zones and site-specific alternative criteria

In addition, constructed wetlands may be appropriate for most land uses, assuming the availability of land. Alternative criteria could also potentially be established for some parameters in order to prevent the water quality criteria from being exceeded.

K12a.Strategies for Canals

Three techniques have been developed for increasing dissolved oxygen in discharges from dams: oxygen injection, air injection, and the construction of spillways and weirs. Oxygen injection involves the use of pure oxygen to increase levels of dissolved oxygen in reservoirs. It could potentially be used to increase dissolved oxygen concentrations in the systems that drain to the lake. Air injection is similar to oxygen injection, but atmospheric air or compressed air is used to increase the dissolved oxygen concentration of the water body. It requires a compressor or other source of air, a diffuser system to distribute the air, and a pipe to deliver the air to the diffusers. Air injection may not be effective for large volume, intermittent flood control flows to the lake. Spillways and weirs could be constructed at the downstream sides of control structures to enhance aeration of water as it flowed over the structures. These techniques could potentially be applicable to the canals and pumped water control structures that are commonly used to control surface water movement in the Lake Okeechobee watershed. In addition, sediment removal from canals and constructed wetlands provide management alternatives that could potentially be used for many land use categories in the watershed.

K12b.Marina Operation Strategies

Marina and boat operations, such as disposal of liquid wastes, and boat maintenance and cleaning can generate surface water pollution. Management strategies that could potentially be applicable to marinas on the lake include liquid waste management and boat maintenance control measures. Liquid waste management involves providing appropriate facilities at marinas for disposal of liquid wastes, such as oil, waste gasoline, solvents, antifreeze, and paints. Boat maintenance control measures include providing designated areas for boat maintenance and repairs, and requiring their use for those activities. It also calls for regular cleaning of the maintenance areas to remove trash, sandings, paint chips, etc. The goal is to reduce the amount of solid wastes that are introduced to surface waters.

Marinas and associated camping areas that have direct runoff into the lake from paved areas should develop and implement stormwater treatment systems. This would reduce the wastes associated with these recreation activities.

K12c.Administrative Measures

Chapter 62, F.A.C., includes provisions that allow for relief from water quality criteria under certain circumstances, such as site-specific alternative criteria and mixing zones. These alternatives differ from the management strategies described previously, because the administrative measures prevents criteria from being exceeded without improving water quality conditions. Administrative relief measures would likely be viewed by FDEP as acceptable only after thorough demonstration that other alternatives to improve water quality conditions are not feasible due to technical or financial limitations.

Surface water quality regulations contained in Chapter 62-302.530, F.A.C., provide for the establishment of site-specific alternative criteria in certain cases when a water body does not meet applicable criteria due to natural conditions or man-induced conditions that cannot be controlled or abated. In addition, the general criteria for surface waters (Chapter 62-302.520, F.A.C.) allow for establishment of alternative dissolved oxygen criteria using the same provisions included in 62-302.800, F.A.C. Site-specific alternative criteria may be approved for specific parameters in all or part of a surface water body.

A mixing zone may be granted to allow alternative criteria for specific parameters within the zone of mixing, provided the applicable criteria are met at the edge of the mixing zone. Chapter 62-4.244, F.A.C., describes the conditions under which a mixing zone may be requested, the criteria used by FDEP to evaluate requests for mixing zones, and the limitations that apply to mixing zones. No mixing zone or combination of mixing zones is allowed to significantly impact the designated uses of the receiving body of water.

A separate mixing zone must be defined for each parameter, and a mixing zone cannot include a nursery area for aquatic biota. Mixing zone dimensions are determined by modeling, using anticipated concentrations of the specific parameter in the receiving water body.